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ENTOMON

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RNA-synthesis in the Oocytes of *Gesonula punctifrons* (Orthoptera:Acrididae) : An Autoradiographic and α-amanitin Inhibition Studies

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ABSTRACT: In insects oogenesis is associated with accumulation of huge amount of proteins in the oocyte. This protein is generally transported to the egg through the haemolymph. In *Gesonula punctifrons* that has panoistic ovary the oocyte nucleus (germinal vesicle) produces different kinds of RNAs. The present investigation has revealed that the germinal vesicle nucleolus synthesises huge amount of rRNA. This has been confirmed by autoradiography and α-amanitin inhibition studies. Further it has been delineated that the follicle cells and oviduct are also actively engaged in RNA synthesis. Some amount of mRNA and tRNAs are also synthesised by the germinal vesicle.

KEYWORDS: *Gesonula punctifrons*, oogenesis, RNA synthesis, autoradiography, α-amanitin inhibition.

INTRODUCTION

Maturation of the ova involves growth and vitellogenesis of the oocytes. In these processes food reserve: proteins, carbohydrates, various RNAs, fats, pigments etc. are laid down in the egg cytoplasm and are involved in subsequent stages of embryonic differentiation. Insect oogenesis and autoradiographic studies have been frequently merged to obtain knowledge on the sites of synthesis, transport and fate of these macromolecules, specially RNAs in various insect spp. (Bier, 1963a,b; Vanderberg, 1963a,b; Bier, 1964; Urbani and Russo-Caia, 1964; Ramamurthy, 1968; Melius and Telfer, 1969; MacGregor and Stebbings, 1970; Mays, 1972; Buning, 1972; Ullmann, 1973). The RNAs are of paramount importance as they bridge the gap between DNA and proteins. For this reason, the RNA synthetic capabilities of oocyte nuclei and follicle cell nuclei along with transport or post-synthetic activity have drawn much attention. In *Rhodnius* (Lutz and Huebner, 1980) and other telotrophic insects it has been established that nurse cells provide developing oocyte with ribosomes, various RNAs, mitochondria and other cytoplasmic constituents (Telfer, 1975). But no such clear cut

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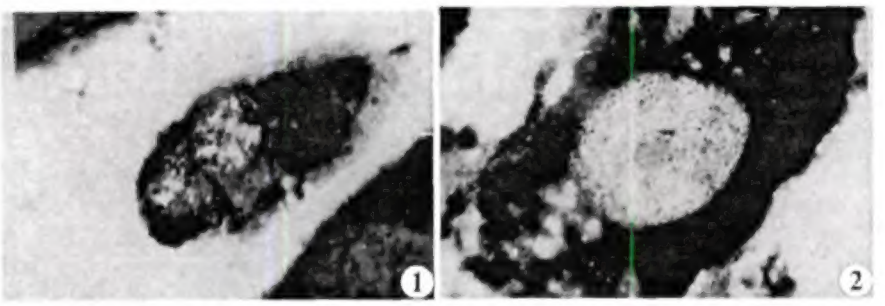

FIGURE 1. The photomicrograph depicting the pattern of incorporation of ^{3}H-uridine in the very young oocytes. Grains present on the follicular epithelium are also shown. Toluidine blue staining. ×920.

FIGURE 2. Photomicrograph of a young oocyte showing the characteristic presence of (a) the central nucleolus like body with silver grains and (b) the array of silver grains giving impression of fibrillar elements radiating from (a). Grains are also present over the follicle cells. Toluidine blue staining. ×920.

picture exist for panoistic type of insects. The present autoradiographic ^{3}H-uridine incorporation study was aimed at shedding light to have a clearer understanding of the RNA synthetic abilities of the different cellular compartments of the reproductive system of *Gesonula punctifrons* (Orthoptera:Acrididae). Furthermore, the toxin α-amanitin has been used to explore the activity of the different RNA polymerases present in the nuclei of the oocyte and the follicle cells. α-Amanitin specifically inhibits the enzyme RNA polymerase II and thereby synthesis of mRNA. So, this experiment along with the ^{3}H-uridine incorporation pattern of the germinal vesicle and follicle cell epithelium explain the involvement of different RNA polymerases in the act of transcription at specific sites such as nucleoplasm, nucleolus-like body, perinuclear dense bodies, etc.

MATERIALS AND METHODS

The female reproductive system of *G. punctifrons* was dissected out in the insect Ringer medium (pH 7.2). The tissue were incubated in Ringer containing ^{3}H-uridine (concentration 200 μCi/ml) for a period of 1 hour to 1.25 hours at room temperature in two experimental sets.

In the inhibition study, the toxin α-amanitin was dissolved in same Ringer solution to get a concentration of 5×10^{-4} M. Excised tissue was incubated *in vitro* for 15 minutes in the Ringer solution containing α-amanitin alongwith ^{3}H-uridine. The tissue incubated only in Ringer solution containing the radioactive tracer served as the control.

After incubation, the tissues were fixed in Carnoy's solution (Ethanol : Chloroform : Acetic acid :: 6 : 3 : 1) for 30 minutes. The tissues were then

processed for paraffin embedding. 6 μ sections were prepared and placed on albuminized slides. Deparaffinized sections were brought down to water through graded ethanol and covered with Kodak AR 10 stripping films. The airdried slides were kept in light proof bakelite boxes containing blue silica gel at 10°–20°C, with an exposure of two weeks. Occational changing of the silıça gel was done to get better result. After exposure, the autoradiograms were developed in D19b at 10°–12°C for 11–12 minutes washed in cold water and fixed in x-ray fixer. The slides were then washed in cold running water for 20–30 minutes. The preparation were stained either in Toluidine blue or Giemsa.

RESULTS

I. Control The nuclei of oocytes in all the stages of growth as a rule incorporate labelled uridine. The number of silver grains and their pattern of abundance vary according to the individual growth stage of the oocyte. In the very young oocytes, i.e., the oocytes in the terminal filament region, the grains show a non-uniform incorporation pattern (Fig. 1). The grains are also found over the more intensely stained nuclear materials which generally remain closely apposed peripherally with the nuclear membrane. The centrally placed nucleolus-like body also shows strong incorporation. A variable number of silver grains are also observed in the cytoplasm near the vicinity of nuclear membrane. The arm-like structures radiating from the central condensed mass within the nucleus also shows linearly arranged silver grains over it (Fig. 2 & 3). In more advanced stages of oocyte, where the yolk deposition is not apparent but the nucleus acquired a larger size, the number of total grains increases considerably. In the approximately full size nucleus the grains were found all over it, with the considerable aggregates of the grains on the centrally placed nucleolus-like structure and the perinuclear dense bodies (Fig. 4). The prevalence of cytoplasmic grains near the perinuclear body apposed to the nuclear membrane indicates possibly the transport of RNA materials at the sites of optimum synthesis (Fig. 5). The incorporation pattern practically dose not show any major alteration in more advanced stages of growth and maturation where yolk deposition and vacuolization of the oocyte cytoplasm occurs. Even at the final stages of oocyte development where nucleolus-like body disappears, the grain count increases, throught the whole nucleus in general, however, no clear picture of transport from the nucleus to cytoplasm would be observed.

During the process of oocyte growth, the follicular epithelium shows sequential changes in many respect, but the incorporation of grain remained a constant feature and the general pattern of this did not vary appreciably. The oocyte cytoplasm in close contact with the follicular epithelium shows presence of a few grains, indicating perhaps the transport of RNA materials from the follicular epithelium (Fig. 4).

The nuclei of the accessory gland cells also showed high numbered depositions of grains. The nucleolar structure showed relatively low grain density than the rest of the nucleus. Cytoplasmic grains are very few in number. The lumen of the accessory gland showed sporadic presence of grains.

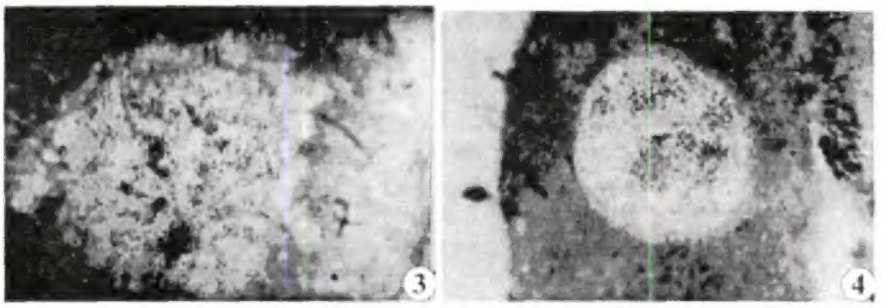

FIGURE 3. Photomicrograph showing differential ^{3}H-uridine differential incorporation pattern of early oocyte. More grains are present over the more basophilic chromatin material, higher degree of incorporation by the nucleolus-like body and cytoplasmic grains near the nucleus. Giemsa staining. ×920.

FIGURE 4. Light microscopic view of an early vitellogenic oocyte showing maximum radioactivity over the central nucleolar body and the perinuclear dense bodies. Grains are also present on the follicular epithelium and the ooplasm facing the former (arrow). Giemsa staining. ×920.

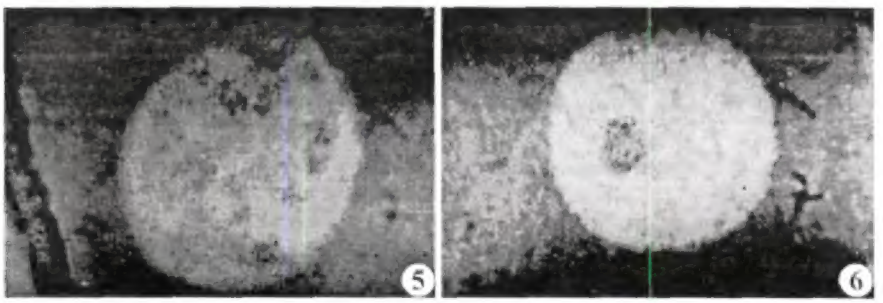

FIGURE 5. Photomicrograph showing the prevalence of ooplasmic grains near the perinuclear body. Giemsa staining. ×920.

FIGURE 6. Higher magnification of germinal vesicle showing presence of fewer grains over the nucleolar body in treated set. Giemsa staining. ×2300.

The incorporation pattern and grain counts of the oviduct cells are almost the same as that of the accessory gland cells.

II. Treated As in the controls the incorporation of labelled elements in the different parts of the reproductive structure was a constant feature. Though the number of grains observed were low in number in comparison with the control, the basic pattern remained unchanged. The nucleolus-like structure showed constant presence of grains (Fig. 6).

The incorporation pattern remains unchanged also for the follicular epithelium, the accessory gland and the oviduct cells.

It was interesting to note that the grain counts in all the structures were diminished to about one third to one fifth of the control experiments. In younger oocytes, oviduct and accessory glands showed more inhibition.

III. Analysis of inhibition For this purpose the counts of various nuclear components were taken and their ratios were analysed. The results are presented in table 1 and table 2.

It was observed that incorporation efficiency was considerably brought down by α-amanitin treatment (Table 1). The high "t"-value indicates the significant decrease in incorporation. The individual ratio of the nuclear and nucleoplasmic grains to the total number of grains present in the nucleus remains almost unaltered (Table 2). These data do not support the hypothesis that α-amanitin preferentially inhibits the synthesis of RNA in nucleolus and nucleoplasm that had taken the label.

DISCUSSION

The localization of silver grains in the autoradiographs of the ovary of *Gesonula punctifrons* clearly indicates the uptake of the labelled uridine. The grain population is higher over the nucleolus-like body and the parts of the nuclear material stained more strongly with Toluidine blue showing the greater involvement in production of the RNA species that are required for the metabolic process of the oocyte. In the advanced vitellogenic stage, the perinuclear dense bodies show highest grain count indicating that those structures are more instrumental in RNA synthetic activity. From this study, it may be suggested that in this panoistic type of ovariole, where there is no nurse cells, the RNA synthesized by those structures is transported to the oocyte cytoplasm and translated to the different proteins coded from mRNAs. Here the RNA synthesized by the oocyte nucleus appears to be the only source for the translation of proteins necessary for growth and differentiation of the oocyte. It seems that the nucleolus-like body is engaged in synthesis of rRNA while the diffused chromatin like organization is involved in production of other RNAs. But in the present study, the presence of nucleolar extrusions was not substantiated.

The distribution of low grain number over the follicular epithelium and those on the oocyte cytoplasm close to the tip of the follicular epithelium suggests low rate of synthesis of RNA by the follicular epithelium and their slow migration / transport to the growing oocyte, while in more developed oocyte the phenomenon of transport is much clearer.

The higher ^{3}H-uridine incorporation pattern in the accessory gland and the oviduct indicate higher rate of synthesis of RNA by these cells and may be utilized for the synthesis of proteins needed for the secretory function. There are reports that ^{3}H-thymidine is also incorporated into the oviductal cells of *Tenebrio* (Ullmann, 1973).

In eukaryotes the process of transcription is accomplished by three different types of RNA polymerases *viz.* I, II and III (Dalgarno and Shine, 1977). These enzymes

TABLE 1. Tabular presentation of grain counts

Series	Nuclear diameter of oocyte in μ	Average no. of grains present[1]				
		on follicular epithelium	on nucleolus-like structure	on nucleoplasm	on total nucleus	on oviduct*
Control	[58 ± 5] (each)	27.3 ± 2.0	50.8 ± 1.87	599 0 ± 27.92	652 8 ± 28.35	125.0 ± 5.0
Treated		9.33 ± 1.5**	15.66 ± 2.0**	160.0 ± 21.00**	205.66 ± 15.96**	45.0 ± 8.0**
Control	[40 ± 4] (each)	19 0 ± 0.78	53.1 ± 2.26	498.88 ± 18.10	552.00 ± 0.3	
Treated		6.62 ± 0.56**	10.76 ± 1.61**	92.07 ± 12.91**	102.8 ± 17.01**	

[1]Randomly chosen *Chosen separately **Significant at 5% level

TABLE 2. Comparison of the ratio counts in the nucleus and its components (nucleolus and nucleoplasm).

Nuclear diameter of oocytes in μ	Series	Ratio of the nucleolar count to total nuclear count $N_1/(N_1 + N_2)$	Ratio of the nucleoplasmic count to total nuclear count $N_2/(N_1 + N_2)$
58 ± 5	Control	0.0778	0.9222
	Treated	0.0761	0.9239
40 ± 4	Control	0.0961	0.9039
	Treated	0.1046	0.8954

differ significantly in their subunits and sensitivity to inhibitors like α-amanitin. Different concentrations of α-amanitin inhibits these enzymes selectively. But the exact nature of inhibition by α-amanitin is not well documented in insects, particularly in female reproductive system. In the present study, with α-amanitin, the ^{3}H-uridine incorporation pattern in early of late oocytes, the oviduct and the accessory gland is dramatically lowered to one third to one fifth of that of the uninhibited ones. But it is apparent to Table 2 that the inhibitor does not preferentially act over the nucleolus-like bodies or ooplasm, rather it brings about an all over inhibition. These results suggest, that both the nucleolus-like body, perinuclear dense bodies and the nucleoplasm possess α-amanitin sensitive RNA polymerase II and thereby are all involved in production of mRNA. A similar result is also observed for oviduct or accessory gland. All these suggest that these sites are more engaged in production of mRNA than any other RNAs.

The presence of ooplasmic grains near the tip of the follicular cells suggest transport of RNAs from present near the germinal vesicle suggest the flow of RNAs from the germinal vesicle to the ooplasm. The conjoined inference from these observations is that in the process of oocyte growth and maturation, the RNA components both from the follicular cells and germinal vesicle take part, and probably the ooplasm is involved in translation.

It may be speculated from the inhibition study that RNA polymerase I and III are less active in the nucleus of this differentiating system. Kastern *et al.* (1981) have shown in *Manduca* that cytoplasm of the matured oocyte contains extraordinary amount of RNA polymerase and 60% of that enzyme (RNA polymerase II) is α-amanitin sensitive. This suggests the possibility that in the process of oogenesis in insects, lower amount of rRNA is produced and stored which is utilized in latter part of embryogenesis, while some of yolk proteins are taken by the developing oocyte from the haemolymph.

ACKNOWLEDGEMENT

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REFERENCES

Bier, K. (1963a) Autoradiographische untersuchungen uber die leistungen des Follikelepithels und der Nahrzellen bei der Dotterbildung und Eiweissynthese im Fliegenovar, *Wilhelm Roux Arch. Entw. Mech. Org.* **154**, 552–575.

Bier, K. (1963b) Synthese, interzellularer Transport und Abbau von Ribonucleinsaure im ovar der Stubenfliege, *Musca domestica. J. Cell Biol.* **16**, 436–440.

Bier, K. (1964) Die Kern-Plasma – Relation und des Riesenwachstum der Eizellem, *Zool. Anz. Suppl.* **27**, 84–91.

Buning, J. (1972) Untersuchungen am Ovar von *Bruchidius obtectus* Say (Coleoptera : Polyphaga) Zur klarung des oocytenwachstums in der Pravitellogenese, *Z. Zellforsch mikrosk. Anat.* **128**, 241–282.

Dalgarno, L. and Shine, J. (1977) In *The ribonucleic acids*, 2nd Ed.. Steward,; Letham.; Springer and Verlag: New York, pp. 195–232.

Kastern, W. H., Underberg, D. A. and Bury, S. J. (1981) DNA-dependent RNA polymerases I and II in insect oocyte, *Dev. Biol.* **52**.

Lutz, D. A. and Huebner, E. (1980) Development and differentiation of an insect telotrophic ovary (*Rhodnius prolixus*), *Tissue and Cell* **12**, 773–794.

MacGregor, H. C. and Stebbings, H. (1970) A massive system of microtubules associated with cytoplasmic movement in telotrophic ovarioles, *J. Cell Sci.* **6**, 431–449.

Mays, U. (1972) Stofftransport im Ovar von *Pyrrhocoris apterus* L. Autographische untersuchungen zum Stofftransport von den Nahrzellen zur oocyte der Feuerwanze, *Pyrrhocoris apterus* (Heteroptera), *Z. Zellforsch. mikrosk. Anat.* **123**, 395–410.

Melius, M. E. and Telfer, W. H. (1969) An autoradiographic analysis of yolk deposition in the cortex of the cecropia moth oocyte, *J. Morph.* **129**, 1–16.

Ramamurthy, P. S. (1968) Origin and distribution of glycogen during vitellogenesis of the Scorpion fly, *Panorpa communis. J. Insect Physiol.* **14**, 1325–1330.

Telfer, W. H. (1975) Development of the physiology of the oocyte-nurse cell synchtium, *Adv. Insect Physiol.* **11**, 223–319.

Ullmann, S. L. (1973) Oogenesis in *Tenebrio molitor*: Histological and autoradiographical observations on pupal and adult ovaries, *J. Embryol. Exp. Morph.* **30**, 179–217.

Urbani, E. and Russo-Caia, S. (1964) Osservacioni citochimiche e autoradiofiche sal metabolimo degli aadi nucleici nella oogenesis di *Dytiscus marginalis* L., *Inst. Sci. Camerino.* **5**, 19–54.

Vanderberg, J. P. (1963a) Synthesis and transfer of DNA, RNA and protein during vitellogenesis in *Rhodnius prolixus* (Hemiptera), *Biol. Bull.* **125**, 556–575.

Vanderberg, J. P. (1963b) The role of the gonadotrophic hormone in the synthesis of protein and RNA in *Rhodnius prolixus* (Hemiptera), *Biol. Bull.* **125**, 576–581.

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Host Plant - Induced Response to Insecticides and Haemolymph Esterase Patterns in American Bollworm, *Helicoverpa armigera* (Hubner)

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ABSTRACT: Third instar larvae of *Helicoverpa armigera* (Hub.) fed on bhendi and tomato were most susceptible followed by those fed on groundnut, cotton, castor and pigeonpea to the three insecticides tested viz. monocrotophos, chlorpyriphos and fenvalerate. The larvae fed on pigeonpea, castor and cotton recorded higher LC_{50} values to the insecticides. Haemolymph esterase patterns revealed that the larvae fed on bhendi and tomato showed six esterase bands each while those fed on pigeonpea recorded thirteen bands. There seems to be a correlation between higher number of esterase bands and the lower toxicity to insecticides.

KEYWORDS: Electrophoresis, Haemolymph esterases, *Helicoverpa armigera* Hub., Host plants, Insecticide susceptibility

INTRODUCTION

The American bollworm, *Helicoverpa armigera* (Hubner) has been posing a serious threat to cotton cultivation in India for the last two decades. Studies on the interactions between host plant, insect and insecticide for a polyphagous pest like *H. armigera* are imperative in view of frequent failures of chemicals to combat the pest on various crops (Reddy *et al.*, 1990). Food being very important component for the polyphagous noctuid, information on the influence of host plants on insecticide susceptibility of *H. armigera* and the associated biochemical changes is vital. Differential response to insecticides in *H. armigera* with reference to hosts was earlier reported by Refai *et al.* (1979) and Loganathan and Gopalan (1985); and the diet dependent esterases were inhibited by esterase inhibitors like monocrotophos (Salama *et al.*, 1992). In the present studies an attempt was made to study the insecticide susceptibility in *H.*

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TABLE 1. Probit analysis of dose-mortality response in third instar larve of *Helicoverpa armigera* fed on different host plants to different insecticides

Insecticide	Host Plant	Chi-Square df = 3	Slope 'b'	LC_{50}	Fiducial limits 95% LL	UL	Relative Tolerance Level*
Monocrotophos	Pigeonpea	0.1974	1.6704	0.2411	0.1609	0.3578	13.69
	Castor	1.5249	2.9231	0.2280	0.1747	0.2826	12.95
	Cotton	0.6006	1.0377	0.1982	0.1275	0.3080	11.26
	Groundnut	0.7717	1.6826	0.0766	0.0438	0.1028	4.35
	Tomato	0.1204	1.7636	0.0308	0.0201	0.0444	1.53
	Bhendi	2.5625	0.9748	0.0176	0.0089	0.0347	1.00
Chlorpyriphos	Pigeonpea	0.0329	1.5480	0.0174	0.0110	0.0265	7.65
	Castor	0.1773	1.4024	0.0091	0.0059	0.0139	3.96
	Cotton	0.2907	1.1504	0.0140	0.0095	0.0208	6.08
	Groundnut	0.0288	1.5379	0.0087	0.0054	0.0133	3.78
	Tomato	2.0055	1.6602	0.0029	0.0019	0.0043	1.26
	Bhendi	0.1876	1.5632	0.0023	0.0014	0.0035	1.00
Fenvalerate	Pigeonpea	0.4448	1.3645	0.5632	0.3320	0.9104	56.88
	Castor	1.7208	1.4113	0.3669	0.2587	0.5203	37.06
	Cotton	0.4253	1.3805	0.3591	0.2132	0.5775	36.27
	Groundnut	0.0846	1.2070	0.2310	0.0999	0.3803	23.33
	Tomato	0.4667	0.1860	0.0132	0.0066	0.0263	1.33
	Bhendi	0.2002	1.4687	0.0099	0.0062	0.0156	1.00

*Relative Tolerance level = LC_{50} on respective host plant/LC_{50} on bhendi

armigera with reference to its six common host plants viz. pigeonpea, castor, cotton, groundnut, tomato and bhendi.

MATERIALS AND METHODS

Larvae of *H. armigera* were reared individually in glass vials (5 × 3 cm) using parts of respective host plants viz. pods of pigeonpea (*Cajanus cajan* (L.) Millsp.), castor leaves (*Ricinus communis* L.), cotton bolls (*Gossypium hirsutum* L.), groundnut leaves (*Arachis hypogaea* L.), tomato fruits (*Lycopersicon esculentum* Mill.) and bhendi fruits (*Abelmoschus esculentus* (L.) Moench.). Newly moulted third instar larvae of second generation were bioassayed against the commercial formulations of monocrotophos (Nuvacron 36 EC), Chlorpyriphos (Radar 20 EC) and fenvalerate (Fenval 20 EC) by topical application of 10 μl of insecticidal solution using acetone as solvent on dorsum of prothorax. The dose-mortality data recorded 24 hrs after treatment were subjected to probit analysis (Finney, 1952). Haemolymph samples of third instar larvae fed on respective host plants was collected by puncturing a proleg and drawing the exuded haemolymph into a glass tube to which a few crystals of 1-phenyl-2-thiourea were added to prevent melanization. The haemolymph sample was centrifuged at 10000 × *g* for 30 minutes and the supernatant was used. Polyacrylamide gel electrophoresis (PAGE) was performed in an electrophoresis unit according to the procedures described by Sadasivam and Manickam (1992). The zymogram was

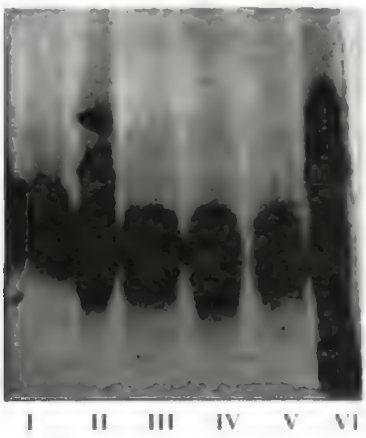

FIGURE 1. Zymogram showing haemolymph esterase patterns in third instar larvae of *Helicoverpa armigera* (Hub) fed on different host plants (1st lane is cotton; 2nd castor, 3rd tomato, 4th groundnut, 5th bhendi and 6th pigeonpea).

prepared and quantified by calculating the relative mobility of isozyme bands.

$$\text{Relative mobility } (R_m) = \frac{\text{Distance moved (cm) by enzyme band}}{\text{Distance moved (cm) by dye front}}$$

RESULTS AND DISCUSSION

Susceptibility of *H. armigera* fed on different host plants to insecticides

Probit analysis of dose-mortality response in third instar larvae fed on different host plants to the insecticides are presented in table 1. In the heterogeneity tests, Chi-square values were found non-significant at 5 per cent level in all bioassays indicating the homogeneity of the test population and a closer fit between observed and expected responses.

Comparison of LC_{50} values of each insecticide against the larvae fed on different host plants revealed that the larvae fed on bhendi and tomato were the most susceptible to the insecticides tested followed by those fed on groundnut, cotton. Larvae fed on pigeonpea and castor, however, were the least susceptible. According to Loganathan and Gopalan (1985) insecticide susceptibility in *H. armigera* was high on tomato and low on pigeonpea. Refai *et al.* (1979) found that tomato fed *H. armigera* was very sensitive to insecticides and this was attributed to nutritional inadequacy of tomato due to higher water content and low content of carbohydrates, fats and proteins. Larvae fed on castor was more responsive to monocrotophos. According to Immaraju *et al.* (1989) higher slope coupled with higher tolerance indicate that the population is becoming less heterogenous. The results also showed that the larvae fed on pigeonpea, castor, cotton and groundnut were 56.8, 37.0, 36.2 and 23.3 times tolerant to fenvalerate

TABLE 2. Relative mobility (R_m) of haemolymph esterases of third instar larvae of *Helicoverpa armigera* (Hub) fed on different host plants and their intensity

R_m	Group*	Number of bands and their intensities					
		Cotton	Castor	Tomato	Groundnut	Bhendi	Pigeonpea
0.24	I	L(1)			L(1)		
0.35	II		L(1)				
0.37	II	L(1)	D(2)		L(1)		D(2)
0.40	II		L(1)				
0.41	II			L(1)	L(1)		
0.42	II						D(4)
0.45	II						D(2)
0.46	II			L(1)			
0.48	II	L(1)	D(2)				
0.50	II				L(1)	L(1)	D(3)
0.51	II						D(2)
0.52	II					L(1)	
0.54	II	L(1)	L(1)	L(1)	L(2)	M(1)	M(2)
0.57	II	M(2)	M(2)	M(2)	M(2)	L(2)	M(2)
0.61	II	M(3)	M(3)	M(3)	M(2)	M(2)	M(2)
0.64	II	M(3)	D(3)	M(3)	M(2)	M(2)	M(2)
0.75	III						L(2)
0.80	III						M(2)
0.86	III						D(2)
0.89	III						M(3)

Figures in parentheses are thickness of bands in mm; L-Light, M-Medium dark, D-Dark bands *Range of R_m values in Group I = 0.00 to 0.24; Group II = 0.35 to 0.64; Group III = 0.75 to 0.89

respectively when compared to bhendi indicating high selection pressure on these crops for synthetic pyrethroids than the organophosphates.

Haemolymph esterase pattern

Electrophoretic pattern of haemolymph esterases revealed that the least number of esterase bands were present in larvae fed on bhendi and tomato (six each) while higher number of bands with higher intensity were found in the larvae fed on pigeonpea (thirteen) and castor (eight) when α-naphthyl acetate was used as a substrate (Fig. 1 and Tab. 2). Larvae fed on groundnut and cotton showed eight and seven bands respectively. The fast migrating bands of the range of R_m 0.75 to 0.89 were deemed to be of lower molecular weight were found only in pigeonpea fed larvae. More number of esterase bands on pigeonpea and castor might have contributed to the higher tolerance to insecticides in *H. armigera*. According to Salama *et al.* (1992) the number of esterase bands in *Heliothis zea* varied with the host plants. Extra esterase bands (Lalah *et al.*, 1995) and the additional esterase bands that were not seen in susceptible aphids may be the one cause of insecticide resistance. O'Brien *et al.* (1992) opined that

increased expression of bands of similar PI values suggested that gene amplification may also cause resistance.

The qualitative and quantitative nutritional factors influenced the ability of insect to synthesize and maintain its detoxification enzymes (Terriere, 1984). Evidently, pigeonpea and castor in the present studies seemed to help the insect synthesize and maintain its detoxification enzymes, particularly esterases, which resulted in higher tolerance to insecticides. The trend clearly indicated that susceptibility decreased with increase of haemolymph esterases in *H. armigera* which were inturn influenced by the quality of food.

Marked differences in enzyme pattern of *H. armigera* fed on different host plants showed that the insect was highly sensitive to host plants. For such insects, any manipulation with regard to host plants will have profound influence on its metabolic system leading to desirable or undesirable effect. This concept was documented by Salama *et al.* (1992) in their studies with *H. zea* and *Heliothis virescens*.

Present findings throw light on the need for crop-based chemical control strategies in Integrated Pest Management (IPM) of *H. armigera* suggesting the possibility of dietary influences on the outcome of pesticide application. This is of prime concern in cropping systems approach in combating the pest species.

REFERENCES

Finney, D. J. (1952) *Probit Analysis*, Cambridge University Press: London, pp. 318.

Immaraju, J. A., Morse, J. G. and Kersten, D. J. (1989) Citrus thrips (Thysanoptera : Thripidae) pesticide resistance in Coachella and Sanjoaquin valleys of California, *J. Econ. Entomol.* **82**, 374–380.

Lalah, J. D., Chien, C. L., Motoyama, N. and Dauterman, W. C. (1995) Glutathione S-Transferases: Alpha-Naphthyl acetate activity and possible role in Insecticide resistance, *J. Econ. Entomol.* **88**, 768–770.

Loganathan, M. and Gopalan, M. (1985) Effect of host plants on the suspectibility of *H. armigera* to insecticides, *Indian J. Plant Prot.* **13**, 1–4.

O'Brien, J., Abdel-Aal, Y. A., Ottea, J. A. and Graves, J. B. (1992) Relationship of insecticide resistance to carboxylesterases in *Aphis gossypii* (Homoptera : Aphididae) from Mid South Cotton, *J. Econ. Entomol.* **85**. 651–657.

Reddy, G. P. V., Murthy, M. M. K. and Prasad, V. D. (1990) Integrated pest management in cotton with special reference to *Heliothis* and *Bemisia* control, In *Recent Developments in the field of pesticides and their application to pest control, Proceedings of the International Seminar held at Shenyang, The People's Republic of China, 8–12 October, 1990.* Holly,; Copping,; Brooks,; 350–370.

Refai, A. EL, Guindy, M. A. EL and Abdel Sattar, M. M. (1979) Variation in sensitivity to insecticides of *Heliothis armigera* fed on different host plants, *Zeitschriff Fur' Angewandte Entomologie* **88**, 107–111.

Sadasivam, S. and Manickam, A. (1992) *Biochemical Methods for Agricultural Sciences*, Wiley Eastern Limited: New Delhi, pp. 246.

Salama, M. S., Schouest, L. P. Jr. and Miller, T. A. (1992) Effect of diet on the esterase patterns in the haemolymph of the corn earworm and the tobacco budworm (Lepidoptera : Noctuidae), *J. Econ. Entomol.* **85**, 1079–1087.

Terriere, L. C. (1984) Induction of detoxification enzymes in insects, *Annu. Rev. Entomol.* **29**, 71–78.

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Oribatid Mites from Weeds-1. A New Species of *Zygoribatula* Berlese, 1916 from *Chromolaena odorata*

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ABSTRACT: The paper illustrates the taxonomic characters of a new species of oribatid mite belonging to the genus *Zygoribatula* viz. *Z. keralensis*. The members of the new taxon were found mainly confined to the lower surface of the crinkled leaves and terminal receptacles of the terrestrial weed, *Chromolaena odorata*. The species was found distributed on the leaves of bitter gourd, *Momordica charantia* also. However, the population density was very low on bitter gourd.

KEYWORDS: Oribatid mites, weed, *Chromolaena*

INTRODUCTION

Berlese (1916) erected the genus *Zygoribatula* based on the type species, *Oribatula connexa*. The genus possesses very high species diversity and enjoys a cosmopolitan distribution. The genus is known to comprise about 120 species distributed in various countries of the world. The known habitats of the members of the genus include moss, leaf litter, tree bark, soil, living plants, cultivated and pasture lands, dry dung and also intertidal zones available in geographically distant localities. The present species resembles several other known species of the genus in sharing an arboreal habitat. The genus is reported for the first time from India.

***Zygoribatula keralensis* sp. nov. (Figs. 1–4)**

Colour: Light brown.
Measurements Length: 306 μm (Range: 268–344 μm)
Width: 166 μm (Range: 140–240 μm)

Prodorsum: (Fig. 1)

Prodorsum broader than longer ending in a conical rostrum; seta *ro* (Fig. 1a) with a blunt apex, inserted far below the rostral apex, thin, barbed, measures 43 μm and sharply pointed. Lamellae ribbon like with wavy surface and thickened, the distance

between the basal part of the lamellae more than twice than that of the distal part, the latter region of the lamellae swollen and cup like; a rod like translamella connects lamellae of the two sides; seta *le* (Fig. 1b) originates from the cup like distal end of the lamellae, measures 40 μm. Seta *in* (Fig. 1c) the shortest among the prodorsal hairs, inserted far below *le* and a little above the dorsosejugal suture, measures 30 μm and densely barbed with blunt apex. Seta *ex* originates laterally, thin and provided with few barbs. Bothridial cups (*bo*) widely open and partially hidden by the anterolateral corners of the notogaster. Sensillus (*ss*) (Fig. 1d) directed anterolaterally with a swollen and spherical head bearing short barbs arranged irregularly. Running somewhat parallel to the lamellae, two lateral ridges present, one on either side of the prodorsum exterior to the bothridia, which slightly converge medially and then diverge peripherally to merge with the prodorsal margin. Prodorsal area lying anterior and posterior to the translamella provided with straight, wavy, curved and narrow striations; micropunctations also present on the prodorsal surface in association with the striations.

Notogaster: (Fig. 1)

Notogaster oval shaped; anterior border of the notogaster convex due to the arched nature of the dorsosejugal suture; fourteen pairs of barbed setae present on the notogaster, which show size variation; c_1 inserted at the extreme anterolateral corner, p_1, p_2 and p_3 with ventral insertions. Five pairs of area porosae of varying size and shape distributed on the notogaster; *Ad* narrow, elongated and located anteriorly; *Aa* rounded and situated in between setae *la* and *da*; A_1 placed below seta *lp*; A_2 situated in between setae h_2 and h_3, more near to the former and A_3 present at the extreme posterior side, just below seta h_1. Punctations and faint striations present on the notogaster irregularly. Fissure *im* narrow, elongated and arranged obliquely in between setae *lm* and *lp*, but aligned internally.

Lateral region: (Fig. 2)

Genal tooth distally pointed. Pedotectum I well developed covering acetabulam I, but not covering the insertion of the exobothridial seta and provided with striae dorsally. Circumpedal carina (*cir*) present, beginning at the base of pedotectum II and extending posteriorad, a little distance behind acetabulam IV. No custodium detected. Area porosa *Ah* clearly visible laterally. Punctations aggregated along the lateral prodorsal surface, particularly near the region of lamellae, bothridia and insertion of seta *ro*.

Ventral region: (Fig. 3)

Gnathosoma (Fig. 3a) Mentum provided with very small, round foveolae distributed irregularly. Labiogenal articulation diarthric type. Setae *a* and *m* roughened; seta *h* also roughened and a little longer than *m*. Rutellum (*ru*) with four, stout notches. Chelicerae (Fig. 3b) elongated and porose on 3/4th of their area; both *cha* and *chb* barbed, the former longer than the latter and tapering distally. Pedipalps (Fig. 3c)

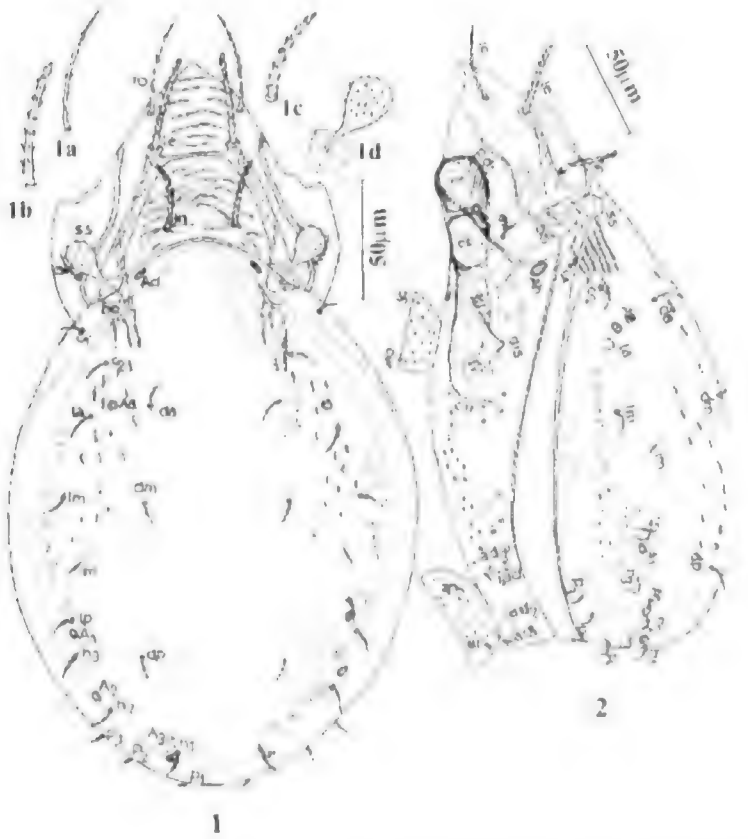

FIGURE 1. *Zygoribatula keralensis* sp. nov. Dorsal region. a) rostral seta; b) lamellar seta; c) interlamellar seta; d) sensillus.

FIGURE 2. *Z. keralensis* – Lateral region.

possess a setal formula of 0–2–1–3–10; most of the palpal setae provided with barbs, on the tarsus (*lt*) and (*vt*) smooth, eupathidium (*acm*) seen closely associated with the solenidion (ω).

Epimeral region

Apodemata II, III and the sejugal apodeme detected; sejugal apodemata of the two sides extend medially forming a spindle shaped structure above the level of the genital plates; seta 3*a* inserted on the spindle; Epimeral setal formula 3–2–3–3; all setae roughened showing variation in size, setae 1*c* and 3*c* barbed, longer and thicker than the rest; epimeral surface foveolated.

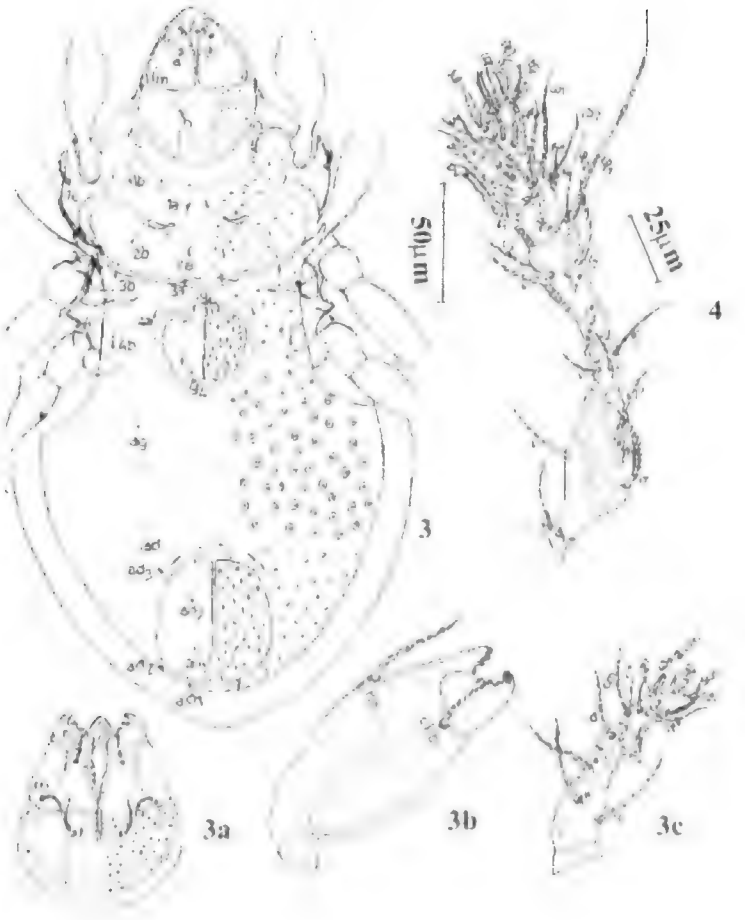

FIGURE 3. *Z. keralensis* – Ventral region; a) gnathosoma; b) chelicera; c) pedipalp.

FIGURE 4. *Z. keralensis* - Leg. I.

Genital and anal regions

Genital plates broader medially, each plate with four smooth setae, the interspace between g_2 and g_3 more than twice than that of g_1 and g_2 and g_3 and g_4. Small foveolae of varying shape present on the genital plates. A pair of smooth, thin aggenital setae (ag) located posterolateral to the genital plates. Anal plates almost rectangular and provided with two pairs of smooth setae; an_1 a little below and an_2 a little above the midline; anal plates also foveloated similar to that of the genital plates. Three pairs of adanal setae detected on the adanal area; ad_1 located posteriorly, ad_2

posterolaterally and ad_3 anterolaterally placed. Fissure *iad* aligned obliquely, anterior to ad_3.

Legs Each leg provided with three unequal claws, the median claw stouter than the two lateral ones. Chaetotaxy of leg I (Fig. 4) 0–5–4–6–21; femur I stout and convex dorsally bearing porose area, seta *d* thick and provided with long, fine barbs; genu I carries a solenidion (σ); tibia I with a dorsodistal projection on which inserted the two solenidia, φ_1 and φ_2, the former stouter and more than twice in length than the latter; on tarsus I, ω_1 more elongated and stouter than ω_2, famulus (ξ) situated proximal to ω_2; all tarsal setae except (p) and *s* barbed in varying degrees.

Materials examined Holotype: ♂; paratypes: 4♂♂ and 5♀♀ collected from the crinkled terminal leaf receptacles of *Chromolaena odorata*, Calicut University Campus, Kerala, India on 22.5.83. Coll. N. Ramani. The holotype and paratypes are deposited in the Department of Zoology, University of Calicut.

Remarks

Among the various species of the genus *Zygoribatula* compared during the study, the present new species resembles three described species viz. *Z. trichosa* Mihelčič (1956) collected and figured by Hammer (1975) from Central Sahara, *Z. schauenbergi* Mahunka (1978) and *Z. lineata* Hammer (1979) in the general shape of the body and in the chaetotaxy of the notogaster, genital and anal plates. However, possession of the following characters separates the new species from the above three species:

1. thick and blunt nature of setae *le* and *in*
2. area porosae *Ad* and *Al*
3. large and spherical head of the sensillus and
4. epimeral setal formula of 3–2–3–3.

REFERENCES

Berlese, A. (1916) Centuria prima di Acari nuovi, *Redia* **12**.

Hammer, M. (1975) On some oribatids from Central Sahara (Acari: Oribatulidae), *Skeenstrupia* **3(18)**, 187–196.

Hammer, M. (1979) Investigations on the oribatid fauna of Java, *Biol. Skr. Dan. Vid. Selsk.* **22**, 1–79.

Mahunka, S. (1978) Neue and interessente Milben aus dem Genfer Museum XXVII. A first survey of the oribatid (Acari) fauna of Mauritius, Reunion and Seychelles. I, *Rev. Suisse De Zool.* **85(1)**, 177–236.

Mihelčič, F. (1956) Oribatiden Sudeuropas V, *Zool. Anzeiger* **157**, 154–174.

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Histolysis and Development of Flight Muscles in *Zygogramma bicolorata*, an Effective Natural Enemy of *Parthenium hysterophorus*

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ABSTRACT: The indirect flight muscles of *Z. bicolorata* were greatly degenerated in adults which are in diapause. Muscle regeneration occurs in adults soon after emergence from diapause. These adults establish themselves rapidly, bringing defoliation of the weed in areas where they infest within one to two months. During this period large scale migration of adults to other areas could be observed. Towards the late season with extensive defoliation, the females cease to oviposit. Congregation of adults on defoliated and dried twigs could be observed under field conditions. These adults were found to have degenerated indirect flight muscles. The present studies reveal that status of the flight muscles could provide a means of analysing the various events occurring in *Z. bicolorata* under field conditions.

KEYWORDS: *Z. bicolorata*, flight muscles, histolysis, regeneration.

INTRODUCTION

The apperance of *Zygogramma bicolorata* Pallister in the field begins with the onset of monsoon rains in May, coinciding with the invasion of the weed, *Parthenium hystereophorus*. The adults remain active in the field from June to October (Jayanth and Geeta Bali, 1994). The adults exihibited varied flight behaviour, during their period of activity. For, in the beginning of the season, adults were not found taking to flight even under forced conditions. With localised defoliation becoming evident in many places, adults were found to fly. Similarly, towards the late season adults were not observed to fly. Aggregation of adults in large numbers covering the defoliated plants was visible in large extended areas.

Various factors like temperature, starvation, mating, overcrowding, hormones were reported to induce flight muscle development in waterhyacinth weevils, Neochetina spp., *Disdercus cingulatus*, and Rice water weevils (Ganga Visalakshy; Mohanan Nair and Prabhu, 1979; Muda *et al.*, 1981). Similarly, physiological activities like diapause induction and termination were found to cause development and degeneration in Rice

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water weevil (Muda *et al.*, 1981). As factors inducing flight behaviour in *Z. bicolorata* were not yet known, the present study was carried out to determine the structure of flight muscles during different periods of the season. This could help us to predict various seasonal activities like diapause, period of maximum reproduction, period of flight etc thereby enabling to understand the potentiality of the insect, in controlling the weed.

MATERIALS AND METHOD

With the appearance of *Z. bicolorata* adults after termination of diapause, about 100 adults were collected at random from parthenium plants infesting in and around I.I.H.R. farm. These adults were brought to the laboratory preserved in 70% Isopropanyl alcohol upto a week This was done at monthly intervals from May/June to Nov/December for the year 1994 and 1995 respectively. Later these adults were embedded in paraffin wax, with their dorsal surface facing upwards dissected with the help of a binocular stereo microscope and details on the status of the flight muscles were made.

In addition 500 adults of *Z. bicolorata* were collected during November from defoliated stands of parthenium and released into diapausing jars. (The diapausing jars were plastic jars of 3 liter capacity with aerated lid. The jar was filled with soil, (5 cms from the base) which is moistened enough to facilitate burrowing of the adults). After 2–3 days, the adults which have not entered the soil for diapause were removed. These dapausing jars were kept under laboratory conditions. From these jars about 25 adults were collected at 15, 30, 45, and 100 days after diapause, preserved in 70% Isopropanyl alcohol, dissected and observations on the structure of flight muscles were made.

Coinciding with the appearance of adults after diapause termination in the field during May, the diapausing jars were moistened enough for diapause breakage of the adults. After 24 hr all the emerged adults were collected, from which a few were preserved in 70% Isopropanyl alcohol. The remaining adults were released into aerated plastic jars, where parthenium bouqets were provided. The bouqets were replaced as and when needed. From these jars about 25 adults were collected at weekly intervals, preserved in 70% Isopropanyl alcohol, dissected and observations on flight muscles were made. In addition, newly emerged adults and adults which were flying were captured using a net, preserved in 70% Isopropanyl alcohol, dissected and observations on flight muscles were made.

In addition to the status of flight muscles, the status of the reproductive organelles (pre-vitellogenesis and Vitellogenisis) of the preserved adults were also observed.

RESULTS AND DISCUSSION

To study the anatomical changes associated with flight muscles, the indirect median dorso longitudinal muscles were considered. (MDL). These were found lying just beneath the methathoraxic tergum, occupying the entire width of the body cavity. Well

TABLE 1. Status of indirect MDL and reproductive organelles (oranioles) of *Z. bicolorata* collected during different seasons (94–95)

Month of collection	% of adults with well developed MDL	% of females with matured ovaries
June	100	–
July	80	85
August	82	80
Sept	68	72
Oct	54	36
Nov	38	30
Dec	28	24

TABLE 2. Status of indirect MDL and reproductive organelles of *Z. bicolorata* collected during different months (95–96)

Month	% of females with well developed MDL	% of females inVitellogenes
May	100	–
June	96.8	18.7
July	96	96.00
Aug	65.85	68.00
Sept	40.28	25.00
Oct	33.57	10.5
Nov	32.87	10.3

developed MDL were thick, compact, conspicous and not ruptured while dissections. As it was difficult to locate degenerated MDL, they were stained with 5% methylene blue for 5 minutes (Mohanan Nair and Prabhu, 1979). MDL which are transparent but having the same width as of developed ones were considered as degenerated, as the process has already started.

Newly emerged adults of *Z. bicolorata* were found to have degenerated flight muscles, which develops within 2–3 days. Adults captured on flight were found to have well developed MDL and the females had matured ovarioles in the follicles.

The status of MDL during different periods of the year were presented in Table 1. Examination of adults within a month of their appearance indicated that all the adults had well developed MDL. About 80–82% of the adults collected in July and August were found to have well developed indirect flight muscles. However, adults could not be observed flying during these periods. By September, localised defoliation of the weed by *Z. bicolorata* was evident. Migration of *Z. bicolorata* by flight to other areas could be observed, during this period. About 68% of the adults examined during this month were found to have well developed MDL capable of flight.

TABLE 3. Status of MDL and reproductive organelles of diapausing adults of *Z. bicolorata*

No. of days in diapause	% of adults with well developed MDL	% of females in vitellogenesis.
0 days		
10	–	–
30	–	
45	–	–
100	–	
0 days after emergence	60	
10 days after emergence	100	100

Biological examination of *Z. bicolorata* adults collected during the late season indicated that flight muscles began to degenerate rapidly once extensive defoliation was observed in and around Bangalore. The steady decline of adults with well developed MDL established that only few adults were able to fly, during the late season. Thus by October, about 54% had well developed MDL which reduced to 38 and 28% in November–December, respectively. Observations made in 1995 also gave similar results. All the adults collected in May had well developed MDL, which reduced to 65.85, 40.28, 33.57 and 32.84% in the months of August, September, October and November respectively. In both years, the period of muscle degeneration coincided with the period of minimum reproduction in the fields based on the percentage of gravid females in the population. (Table 1).

Diapausing adults of 0, 15, 30, 45 and 100 days were also found to have thin transparent degenerated MDL. However within a few hours 60% of the population developed MDL, capable of flight. By one week all the diapause emerged *Z. bicolorata* had well developed MDL capable of flight. Muscular tissue changes observed in *Z. bicolorata* were found to be similar to that reported in Rice Water Weevil (Muda *et al.*, 1981) with respect to diapause emerging and diapause entering adults. However unlike reported in Rice water weevil, the period of flight muscle degeneration was not found coinciding with the period of maximum reproduction in *Z. bicolorata* adults.

Coinciding with diapause behaviour, variation in fat body accumulation was also noticed. Normal non-diapausing adults were found to have 10% of the body cavity with thin fragmented fat bodies. The body cavity of adults which are to diapause were found bulging, with the time of various events observed in the study like flight, diapause initiation, diapause termination and period of maximum reproduction could be predicted based on the status of indirect flight muscles. During the starting of the season though the adults had well developed MDL they were not observed to migrate by flight. Only with the depletion of food adults started to migrate to other areas in search of food, indicating that depletion of food induces flight behaviour in *Z. bicolorata*. Absence of food has been reported to initiate flight behaviour in

Neochetina bruchi and *N. eichhorniae*, potential natural enemies of water hyacinth (Ganga Visalakshy In press). The present study shows that majority of adults examined in October–December have degenerated MDL, where by not capable of flight. This explain the congregation of adults on defoliated twigs towards the late season. Thousands of diapausing adults of pine bark beetles were reported to congregate on the barks of the trees and this is considered as an adaptation for easy mating and early population build up for the succeeding season (Wolda, Denlinger, 1984). In *Z. bicolorata* also, the adults within 2–3 hrs. of emergence from diapause was found to mate and females started laying eggs within 3–4 days.

Coinciding with the defoliation of the weed, the percentage of females with matured ovarioles was found reducing. This indicates that with the progression of the season the number of new adults added to the population decreases. Thus, it may be advisable to make new releases during the initial period whereby rapid multiplication and suppression of the weed could be achieved within a short time.

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REFERENCES

Ganga Visalakshy, P. N. Flight muscle development in *Neochetina eichhorniae* Warner and *N. bruchi* Hustache, potential biocontrol agents of water hyacinth, *Insect Science and its Application* **(In Press)**.

Jayanth, K. P. and Bali, G. (1994) Biological studies on *Zigogramma bicolorata* Pallister (Coleoptera: Chrysomelidae), a potential biological agents of *Parthenium hysterophorus* L. (Asteraceae), *Journal of Biological Control* **7**, 93–98.

Mohanan Nair, C. R. and Prabhu, V. K. K. (1979) Effect of starvation, mating, ovariectomy and juvenile hormone analogue on indirect flight muscle histolysis of *Disdercus cingulattus*, *Entomon* **4**, 285–288.

Muda, A. R. B., Tugwell, N. P. and Hazlip, M. P. (1981) Seasonal and indirect flight muscle degeneration and regeneration in Rice Water weevil., *Environmental Entomology* **10**, 685–690.

Wolda, H. and Delinger, D. L. (1984) Diapause in a large aggregation of a tropical beetle., *Ecol. Ent.* **47**, 369–381.

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Seasonal Abundance of Pomegranate Butterfly, *Deudorix isocrates* Fabricius

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ABSTRACT: Investigations on population dynamics of pomegranate butterfly (*Deudorix isocrates* Fabr.) in different fruiting seasons of pomegranate were conducted during March, 1991 to February, 1993. The activity of the pest was least during March to June while the period from July to October was more favourable for its build-up. The period from November to February was of medium order. The egg parasitoid (*Telenomus* sp.), larval parasitoid (*Apanteles* sp.) and pupal parasitoid (*Brachymeria lasus* Wlk.) as well as the adverse weather conditions played an important role in reducing the pest population.

KEYWORDS: Pomegranate, *Deudorix isocrates*, abundance spring, summer, parasitoid.

INTRODUCTION

The insect, *Deudorix (Virachola) isocrates* Fabr. is the most common pest of pomegranate crop in India. It is also called as anar caterpillar or pomegranate fruit borer. The incidence of the pest has been reported throughout the year with varying degree of intensity in Maharashtra and Karnataka (Halleppanvar, 1956; Zirpe, 1966; Kabre, 1986) and sometimes it may cause 100 per cent damage of the fruits (Halleppanvar, 1955). This pest is the major limiting factor in pomegranate farming in Maharashtra State. Looking to the economic importance of the pest an attempt was made to investigate to find out the seasonal fluctuation in the population build-up in relation to biotic and abiotic factors.

MATERIALS AND METHODS

These studies were carried out during three consecutive years from March, 1990 to February, 1993, comprising of all the three fruiting seasons of each year (Spring, Rainy and Winter).

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TABLE 1 Average incidence of pomegranate butterfly in relation to parasitoids and weather factors (Pooled means of three years : 1990-93)

Season	Month	Infested fruits (%)	Parasitisation due to (%)			Weather factors					
			Telenomus sp	*Apanteles* sp	*Brachymeria* sp.	Temperature (°C)		Relative Humidity (%)		Daily Sunshine period (Hrs)	Rainfall (mm)
						Maximum	Minimum	Morning	Afternoon		
Spring	Mar.	1.84	25.4	11.7	1.3	35.2	14.7	59.7	20.6	10.0	0.0
	Apr.	1.87	17.3	6.7	1.0	37.7	18.8	57.9	24.5	9.9	5.8
	May	1.76	10.3	2.5	0.8	38.3	22.9	67.3	30.3	8.8	41.8
	Jun.	1.98	13.8	5.8	0.3	33.0	23.1	82.7	55.5	5.4	21.84
	Average	1.86	16.7	6.7	0.8*	—	—	—	—	—	—
	S.D.	±1.25	±6.5	±4.1	±0.5						
Rainy	Jul.	4.38	16.0	8.0	0.7	30.0	22.6	82.7	62.9	3.8	68.4
	Aug.	10.07	26.7	16.7	1.7	29.2	21.8	85.8	67.5	3.0	84.6
	Sep.	13.32	31.3	19.2	2.9	31.3	20.5	83.8	53.3	6.7	81.4
	Oct.	12.00	25.3	5.7	3.3	31.1	17.3	79.9	41.0	7.7	118.7
	Average	9.94	24.8	12.4	2.1	—	—	—	—	—	—
	S.D.	±4.00	±8.3	±6.6	±1.2						
Winter	Nov.	8.12	12.5	16.4	2.1	29.6	15.3	78.0	40.0	8.0	3.2
	Dec.	2.25	6.7	16.7	2.1	28.2	10.3	77.5	34.0	8.9	0.0
	Jan.	1.89	3.7	14.0	1.7	29.3	9.6	73.8	29.3	9.4	0.0
	Feb.	2.12	17.2	18.3	2.5	31.5	10.7	68.1	22.3	9.7	0.0
	Average	3.59	10.0	16.3	2.1	—	—	—	—	—	—
	S.D.	±3.46	±6.9	±4.2	±0.8						

The studies were conducted in well-established pomegranate orchard which was planted in July, 1986. Total fourteen trees were selected for the study during each season. There were three separate adjacent experimental blocks for each season. These trees were kept free from insecticidal application during the period of experimentation.

Observations were recorded at the end of each meteorological week commencing from fruit-set till harvest of fruits (four months) corresponding to the periods of March to June for spring, July to October for rainy and November to February for winter seasons, respectively. Total number of fruits and fruits infested by the insect were recorded at each observation and the infested fruits were removed. Percentages of infested fruits were worked out. The monthly averages of per cent infestation were also worked out for each fruiting season.

As regards the biotic factors, the observation was made at weekly interval on the intensity of natural enemies *viz*., egg, larval and pupal parasitoids of pomegranate butterfly. For this purpose, twenty eggs, larvae and pupae of the pest were collected at weekly interval from the separate pomegranate orchard where no protection measure was adopted. These stages of the pest were reared in laboratory to record the emergence of parasitoids. The number of parasitised eggs, larvae and pupae were noted and their percentages of parasitization were worked out. The taxonomic identity of parasitoids was obtained through International Institute of Entomology, London.

The data in respect of maximum and minimum temperatures, relative humidity at morning and afternoon, rainfall and daily sunshine hours during the experimental periods were recorded. The correlation coefficients (r) between the incidence of pomegranate butterfly and natural enemies as well as weather parameters were also calculated.

RESULTS AND DISCUSSION

The data on monthly averages of incidence of pomegranate butterfly, parasitisation of the pest by various bioagents and the weather parameters prevailed during the observation period are presented in Table 1.

The average incidence of pomegranate butterfly was found to be the minimum (1.76%) in the month of May, which steadily increased upto September (13.32%) and declined gradually thereafter. The period between August to October was observed to be the most congenial for development of pest during which the average pest infestation was more than 10 per cent.

Amongst the various fruiting seasons, spring was found to be unfavourable for the pest build-up (1.86% infestation) followed by winter (3.59%) as moderately favourable. The rainy season was the most congenial (9.94%) for the population build-up of *D. isocrates*.

Trehan (1956) reported the pomegranate butterfly most active in summer in Punjab; while in Rajasthan and Himachal Pradesh, it was most severe in the month of July (Pareek, 1982; Patyal and Nath, 1993). Such variation in peak period of incidence of pest might be probably due to the changes in fruiting periods and climatic conditions in different parts of the country.

TABLE 2. Correlation coefficient (r) of the incidence of pomegranate butterfly with biotic and abiotic factors

Environmental factors		Values of Correlation coefficient (r)
A]	Biotic:	
	1. *Telenomus* sp.	+0.458*
	2. *Apanteles* sp.	+0.089
	3. *Brachymeria* sp.	+0.213*
B]	Abiotic:	
	1. Maximum temperature	−0.303*
	2. Minimum temperature	+0.214*
	3. Morning relative humidity	+0.447*
	4. Afternoon relative humidity	+0.417*
	5. Sunshine hours	−0.304*
	6. Rainfall	+0.077

*Significant at 5 per cent level.

As regards the natural enemies, the egg parasitoid, *Telenomus* sp. (Hymenoptera : Scelionidae), larval parasitoid, *Apanteles sauros* Nixon (Hymenoptera : Braconidae) and pupal parasitoid, *Brachymeria lasus* (Walker) (Hymenoptera : Chalcididae) were observed with varying degree of intensity. The egg parasitoid, *Telenomus* sp. was recorded throughout the year; however, it was most abundant in September (31.3%). In general, the parasitisation of the eggs was more pronounced during rainy months (24.8%) as compared to spring (16.7%) and winter periods (10.0%).

Maximum occurrence of larval parasitoid (*Apanteles sauros*) was registered in the month of September (19.2%) as against the least larval parasitisation during May (2.5%). On an average, 6.7 per cent larvae of pomegranate butterfly were parasitised during spring followed by 12.4 and 16.3 per cent during rainy and winter periods, respectively.

Negligible occurrence (< 3.3%) of the pupal parasitoid (*Brachymeria lasus*) was found throughout the year. Similarly, no remarkable difference in the intensity of this parasitoid was noticed during different fruiting seasons. On an average, 0.8% pupae of pomegranate butterfly were parasitised during spring as compared to 2.1% during rainy and winter seasons.

Amongst these parasitoids, *Telenomus* sp. and *Apanteles* sp. played a significant role in keeping the pest population under check. The incidence of *D. isocrates* would have been much more severe than that it had been recorded if there would have not been an average of 16.7, 24.8 and 10.0 per cent egg parasitisation and 6.7, 12.4 and 16.3 per cent larval parasitisation of the pest during spring, rainy and winter seasons, respectively. These indigenous parasitoids could be more promising in integrated management of *D. isocrates*.

As regards to the influence of these parasitoids and weather factors on the incidence of pomegranate butterfly, it could be seen from the correlation coefficients amongst these attributes (Table 2) that the occurrence of all these parasitoids was positively

correlated with the pest population. Especially there was a significant positive correlation between pest incidence and the egg parasitoid, *Telenomus* sp. as well as pupal parasitoid, *B. lasus*. Thus, the increase in pest population encouraged the population build-up of these parasitoids. Similarly, the moderate weather conditions coupled with high humidity in rainy months might have also resulted as congenial conditions for increase in the occurrence of all these parasitoids. According to Patel *et al.* (1997) the activity of *Telenomus* sp. remains high when variation in temperature was low and the relative humidity was high. The increase in the intensity of parasitoids during rainy season and the adverse weather factors from December to June may be responsible in reducing the subsequent build-up of pest population during winter and spring seasons.

The weather factors exerted their specific impact on the pest build-up. Especially, the increase in pest incidence during rainy season was mainly due to moderate temperature and high humidity. There was a significant negative correlation of the pest population with maximum temperature and day length; while it was positively correlated with minimum temperature and relative humidity. In general, the temperature above 33°C and an average day length of more than 8 hours were unfavourable for the pest build-up; while morning relative humidity between 78.0 and 85.8 per cent and afternoon relative humidity between 40.0 and 67.5 per cent were found to be congenial for increase in the occurrence of pomegranate butterfly.

REFERENCES

Halleppanvar, N. L. (1955) The pomegranate fruit borer, *The farmer* **6(12)**, 59–60.

Halleppanvar, N. L. (1956) Important insect pests of fruit crops in Bombay, Karnataka and their control. Pests of pomegranate, *Farmer* **7(6)**, 95.

Kabre, G. B. (1986) *Studies on life history, seasonal incidence and field evaluation of insecticides against fruit borer, Virachola isocrates* Fab. of pomegranate. *Punica granatum* L.M.Sc. (Agri.) Thesis, Mahatma Phule Krishi Vidyapeeth: Rahuri.

Pareek, O. P. (1982) Survey, *Collection and identification of pomegranate pests at Udaipur*, Pomegranate research report and appraisal, pp. 7.

Patel, J. R., Patel, B. H. and Patel, N. C. (1997) Research highlights on vegetable crop pests in middle Gujarat, Department of Agril. Entomology, B.A. College of Agriculture, G.A.U.: Anand, pp. 3–4.

Patyal, S. K. and Nath, A. (1993) Efficacy and persistency of monocrotophos and phosphamidon on wild pomegranate, *J. Ent. Res.* **17(2)**, 111–116.

Trehan, K. N. (1956) Brief notes on crop pests and their control in the Punjab (India), *J. of Bom. Nat. Hist. Soc.* **54(3)**, 620–621.

Zirpe, A. G. (1966) Pests of pomegranate and their control in Maharashtra State. M.Sc. (Agri.) thesis, University of Poona.

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Medically Important Mosquitoes of the World's Largest River Island, Majuli, Assam

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ABSTRACT: Entomological studies were conducted in Majuli, the largest river island of the world during 1996. This is the maiden study and documentation of mosquito fauna of this unique ecosystem. Surveys were carried out during the months of April and October (pre and post monsoon seasons), 1996 to find out the mosquito species, particularly, the disease vectors prevalent in this island. This island is devoid of forests or hills. Bamboo and banana plantations are abundant along the sides of the roads and embankments. Entomological collections were made by collecting both immatures and adult mosquitoes. In immature surveys, a total of 18 species under 6 genera were collected from different habitat types. In adult collections, a total of 28 species under 5 genera were collected which includes the potential vectors of Japanese encephalitis (JE). None of the primary malaria vectors were detected and moreover, no indigenous malaria cases have been reported from this island. Only two clinically suspected cases of JE have been reported in 1996. Presence of the potential dengue vector, *Aedes albopictus*, and abundance in breeding habitats of these mosquitoes in the island is also noteworthy.

KEYWORDS: Mosquito fauna, Majuli river island, Vectors.

INTRODUCTION

The monographs on Indian anophelines and culicines published by Christophers (1933) and Barraud (1934) are the only documents with coverage of the mosquitoes of some parts of Assam. Comprehensive recent information on distribution of mosquito species in northeastern region of India is very meager. In Assam, survey of mosquitoes was first carried out by Challam (1923). Subsequently, several such studies were carried out in various places of the state (Sankar *et al.*, 1981; Kareem *et al.*, 1983; Rao, 1984; Malhotra, 1985). Majuli (meaning island in Assamese language) is the largest river island of the world created by the mighty river Brahmaputra and has a unique ecosystem distinct from other parts of Assam. No previous study on entomological aspects had been carried out in this island. Present surveys were conducted during pre and post monsoon seasons in 1996 as most parts of the island remain inaccessible

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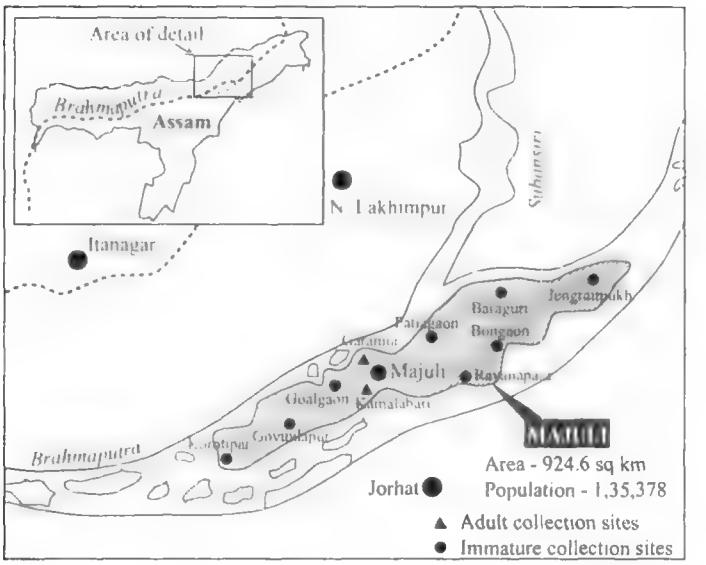

FIGURE 1. Map Majuli Island, Assam, showing the location of collection sites.

during the rainy season due to frequent flooding by the river Brahmaputra. It has been considered of special interest to know the mosquito fauna and to mark out the potential disease vectors prevalent in this river island.

MATERIAL AND METHODS

Study Area

The river island Majuli is located between 26°45′–27°10′ North Latitude to 93°45′–94°30′ East Longitude in Assam. This island has a land area of 924.6 sq km and a population of about 1,35,378 (Fig 1). Assam state has varied ecological niches like dense forest, forest fringes, hills and foot-hills, tea plantations, paddy fields, small valleys with rivers and rivulets. Contrary to this, Majuli island consists of large swampy areas and large water bodies viz. bheels, ponds, etc. Small water collections are very sparse due to loamy absorbent nature of the soil throughout Majuli. No dense forests or hilly areas are located on this island. Bamboo and plantain plantations are seen along the sides of the roads and embankments. Most of the areas are inundated by flood waters of the river Brahmaputra every year. Due to bad conditions of the roads, vehicular traffic is very limited and small boats or machine boats are the main communication means. Movement of the people from other areas is very limited and small boats or machine boats are the main communication means. Movement of the people from other areas is very restricted. The area is totally free from industrial pollution. Due to abundance of large water bodies in the island, fishing is one of the main earning sources of many of the inhabitants. About 50 percent of the inhabitants

TABLE 1. Types of breeding habitats and the immature mosquito collections in Majuli

Ground Water Habitats	Container Habitats
Paddy Field	Bamboo Stump
Cx. bitaeniorhynchus	*Ae. pseudotaeniatus*
Cx. vishnui	*Ae. annandalei*
Cx. gelidus	*Ae. albopictus*
An. hyrcanus s.l.	*Ar. kuchingensis*
Cx. fuscanus	
Drain Water Pool	Plantain Stump
Ae. lineatopenis	*Ae. pseudotaeniatus*
Cx. fuscanus	*Ar. kuchingensis*
	Tx. splendens
Mud Pool	Artificial Container
An. vagus	*Ae. albopictus*
An. hyrcanus s.l.	
Ae. vexans	
Cx. vishnui	
Cx. fuscanus	
Irrigation Channel	
An. kochi	
Ae. lineatopenis	
Cx. vishnui	
Ponds	
Ma. annulifera	
Ma. uniformis	
An. barbirostris	
An. philippinensis	

belong to Mishing tribe and reside in their typical 'Chang' (= platform) houses mostly located at the periphery near the river shores and they customarily rear pigs. Non-tribal people strictly avoid rearing of pigs or poultry. There is only one Primary Health Centre (Kamalabari PHC) with 3 mini-PHCs, 4 dispensaries and 35 subcentres in Majuli.

Entomological Study

Mosquito surveys were conducted during the months of April and October 1996. These pre and post monsoon months were chosen because they seem to be the most mosquitogenic from a study of the flooding periodicity in this island as the island is inundated by the Brahmaputra flood waters during the lengthy span of heavy shower months (monsoons) from May to August. Immature mosquito collections were made from different localities of Majuli viz. Boroguri, Jengraimukh, Bongaon, Ravanapara, Patiagaon, Korotipar, Govindapur and Gualgaon and were link-reared for

TABLE 2. Vector mosquito density and status of vector borne diseases in Majuli

Disease	Potential vectors	*Density/light trap	Cases	Remarks
Malaria	*An. philippinensis*	1	4	imported
	An. annularis	7		cases
JE	*Cx. vishnui*	215	2	suspected
	Cx. gelidus	103		
	Cx. whitmorei	87		
	Cx. pseudovishnui	49		
	Cx. tritaeniorhynchus	40		
	Cx. bitaeniorhynchus	11		
	Cx. fuscocephala	8		
	Cx. quinquefasciatus	2		
	An. hyrcanus	57		
	Ma. uniformis	62		
	Ma. annulifera	13		
Filariasis	*Cx. quinquefasciatus*	2	nil	
	Ma. uniformis	62		
	Ma. annulifera	13		
	Ma. dives	1		
	Ma. indiana	10		
Dengue	*Ae. albopictus*	0.3	nil	

*Results of collection of 4 night-traps.

identification. For adult collection throughout the night, CDC (Communicable Disease Centre, USA) miniature light traps were operated in Garamur and Kamalabari areas. Almost all the cattle sheds had giant sized plastic nets to protect their cattle from the mosquito bites and therefore the net had to be raised partially from the study shed on the particular night for operating the CDC light trap. Daytime outdoor adult mosquito resting surveys were performed by using drop nets on bushes and shrubs and collecting the mosquitoes trapped inside by sucking tubes and daytime indoor resting mosquito surveys were performed by using sucking tubes and flash lights from the nooks and corners and under beds etc. of houses. Collected specimens were brought to the field laboratory for identification by following standard identification keys.

RESULTS AND DISCUSSION

A total of 18 species of mosquitoes belonging to 6 genera were collected during immature surveys from 8 different habitat types viz., bamboo stumps, paddy fields, rainwater pools, plantain stumps, irrigation channels, artificial containers, pools and ponds (Table 1). The maximum (4–5) species were collected from paddy fields, mud-pools, ponds and bamboo stumps. In CDC light traps operated for 4 nights (one trap per night) in Garamur and Kamalabari areas, a total of 3094 mosquitoes belonging to 28 species under 5 genera were collected. Predominant among the collections

TABLE 3. Record of day-time resting mosquito collection

Species	Indoor resting							Outdoor resting						
	Male	Female	*F Ab-St				Total	Male	Female	*F Ab-St				Total
	No.	No.	UF	FF	SG	G		No.	No.	UF	FF	SG	G	
An. hyrcanus gr.	0	2	2	0	0	0	2	2	2	2	0	0	0	4
An. annularis	0	1	0	1	0	0	1	0	0	0	0	0	0	0
An. vagus	2	3	0	0	0	3	5	1	0	0	0	0	0	1
Cx. quinquifasciatus	1	8	3	2	0	3	9	0	0	0	0	0	0	0
Cx. vishnui	2	7	5	1	0	1	9	32	58	17	30	1	10	90
Cx. tritaeniorhynchus	0	1	1	0	0	0	1	0	3	2	1	0	0	3
Cx. pseudovishnui	2	2	2	0	0	0	4	32	53	38	11	0	4	85
Cx. bitaeniorhynchus	0	0	0	0	0	0	0	3	3	3	0	0	0	6
Cx. gelidus	0	1	0	0	0	1	1	5	3	1	1	0	1	8
Cx. fuscocephala	0	1	0	1	0	0	1	0	1	1	0	0	0	1
Ma. uniformis	4	15	2	12	0	1	19	22	33	18	9	2	4	55
Ma. annulifera	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Ma. dives	0	1	1	0	0	0	1	0	1	0	0	0	1	1
Cq. crassipes	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ae. lineatopenis	0	0	0	0	0	0	0	0	2	1	1	0	0	2
Ae. vexans	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Ar. kuchingensis	0	0	0	0	0	0	0	4	3	2	1	0	0	3
Total	11 (20.76)	42 (79.24)	16 (38.09)	17 (40.47)	0 (0.00)	9 (21.44)	53	102 (38.35)	164 (61.65)	86 (52.44)	54 (32.92)	3 (1.83)	21 (12.81)	266

Figures in parentheses are percentage values. *Female's Abdominal status. UF = Unfed, FF = Full fed, SG = Semi-gravid, G = Gravid

TABLE 4. Non-vector mosquitoes in Majuli Island

Of Pestiferous value	Of no Pestiferous value
An. splendidus	*Tx. splendens*
An. tessellatus	
An. kochi	
An. vagus	
Ar. kuchingensis	
Ar. obturbans	
Ae. lineatopenis	
Ae. pseudotaeniatus	
Ae. vexans	
Ae. chrysolineatus	
Ae. annandalei	
Cx. (Lut.) fuscanus	
Ma. (Coq.) crassipes	

were potential JE vectors (Rodrigues, 1984) belonging to 11 species under 3 genera comprising 83% of the total mosquitoes trapped (Table 2).

A total of 266 mosquitoes representing 15 species were trapped in outdoor drop net collections (operated 7 times) from the vegetation on outskirts of human habitations (Table 3). *Cx. vishnui* (90) was the highest in number followed by *Cx. pseudovishuni* (85) and *Ma. uniformis* (55). Rest of the species were found in numbers less than 10. 38% of the above collection comprised of males Out of the females, 52% were unfed whereas the rest were either full-fed or gravid. In the indoor daytime searchers, conducted in 10 randomly selected houses (15 min per house),

53 mosquitoes belonging to 11 species were collected of which about 79% were females. Almost equal numbers of full-fed and unfed mosquitoes were found with gravid mosquitoes comprising 21% of the total female catch. The results of day-resting collection which include mostly the potential JE vectors revealed that there is fourfold preponderance of most of the species in outdoor as compared to indoor indicating their nature of exophily.

Almost all the potential JE vectors incriminated from different regions of India (Chakravarti *et al.*, 1981; Rodrigues, 1984; Mourya *et al.*, 1989; Dhanda *et al.*, 1997) were trapped during the survey in large numbers in all the collection methods employed. From Jengraimukh mini PHC, only two suspected cases of JE had been reported during 1996 and these cases were referred to the Civil hospital, Jorhat (personal communication, Medical Officer, Jengraimukh Mini PHC). Factors like presence of vector species in substantially large numbers, migratory ardeid birds, a large pig population and a congenial ecosystem for transmission of JE are prevailing in this island. Moreover, a unique feature of this place is the use of very large synthetic (plastic/nylon) mosquito nets to protect their cattle from mosquito bites. However, the pigs reared by the Mishing tribe people were not covered in mosquito net enclosures.

Most of the people of all communities in this island also use bednets. Due to its isolation from the mainland, the inhabitants of this island may not be getting the JE infection. Moreover, personal protection measures like use of bednets to avoid the nuisance caused by the pestiferous mosquitoes (Table 4) also may be instrumental in keeping the vectors at bay. But it would be premature to make any comments on the JE virus activity in the island without conducting vector incrimination studies or serological study of pigs and the ardeid birds which is very much warranted. Anyway, the possibility of carrying infection of JE by the migratory birds and pigs brought for rearing from the adjacent mainland areas viz. Dhemaji, Dhakuakhana and North Lakhimpur (endemic for JE) to this island cannot be ruled out in the near future. The presence of potential dengue vector, *Ae. albopictus* and its different breeding habitat types in the island is noteworthy. From our immature and adult mosquito collections, no major vector of malaria was detected. Moreover, no indigenous malaria cases are reported. Only in Jengraimukh mini PHC, 4 cases of malaria were reported in 1995 and all of them were imported cases from adjoining Gogamukh area of North Lakhimpur district (NMEP records). Climate, geography and other factors have an influence on mosquito population and their consequential role in disease transmission. More detailed analyses of relationship between vector mosquito population dynamics and disease transmission is required in future studies.

REFERENCES

Barraud, P. J. (1934) *The fauna of British India, Diptera; Volume-V*. Family Culicidae, Tribe Megarhinini and Culicini. Tailor and Francis: London, p. 463.

Chakravarti, S. K., Chakraborty, A. K., Mukherjee, K. K., Mitra, A. C., Hati, A. K. and Chakraborty, M. S. (1981) Isolation of Japanese encephalitis virus from *Mansonia annulifera* species of mosquitoes in Assam, *Bull. Calcutta Sch. Trop. Med.* **29**, 3–4.

Challam, B. S. (1923) Some notes on malaria investigations in a sugarcane state in Kamrup, Assam, *Indian Med. Gaz.* **58**, 476–479.

Christophers, S. R. (1933) *The fauna of British India, Diptera, Volume-IV*. Family Culicidae, Tribe Anophelini. Tailor and Francis: London, p. 371.

Dhanda, V., Thenmozhi, V., Kumar, N. P., Hiriyan, J., Arunachalam, N. and Balasubramanian, A. *et al.* (1997) Virus isolation from wild-caught mosquitoes during a Japanese encephalitis outbreak in Kerala in 1996, *Indian J. Med. Res.* **106**, 4–6.

Kareem, M. A., Singh, Y. K., Bhatnagar, V. N. and Dass, M. A. (1983) Preliminary report of entomological study under PfCP in zone-I, *J. Comm. Dis.* **15**, 207–208.

Malhotra, P. R. (1985) Mosquito fauna of Assam and their role in disease transmission, *J. Assam Sci. Soc.* **28**, 25–28.

Mourya, D. T., Ilkal, M. A., Mishra, A. C., Jackob, P. G., Pant, U. and Ramanujan, S. *et al.* (1989) Isolation of Japanese encephalitis virus from mosquitoes collected in Karnataka state, India from 1985–1987, *Trans. R. Soc. Trop. Med. Hyg.* **83**, 550–552.

Rao, T. R. (1984) *The Anophelines of India*, Malaria Research Centre, ICMR: Delhi, p. 518.

Rodrigues, F. M. (1984) Epidemiology of Japanese encephalitis in India: A brief overview, In. *Proceeding of the National Conference on Japanese encephalitis*, Indian Council of Medical Research: New Delhi, 1–9.

Sarkar, P. K., Das, N. G. and Rao, K. M. (1981) Mosquito fauna in certain places of Dibrugarh district in Assam, *Indian J. Med. Res.* **73**, 331–334.

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Behavioural Adaptations to Temperature Variations in the Burrowing Scorpion, *Heterometrus Fulvipes* (C. L. Koch)

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ABSTRACT: The burrow morphology and the daily burrow activities of the field scorpion, *Heterometrus fulvipes* were studied. Temperature variations within the burrow were measured with a thermister and outside temperatures with a thermometer, over a period of eight months. The susceptibility of scorpions to both high and low temperatures was also studied. The burrow temperatures are lower by 1 to 8°C when the outside temperatures are maximal and higher by 1 to 6°C when outside temperature are minimal. Thus *H. fulvipes* lives in a relatively constant environment by confining to the burrow when outside temperatures are high and begins surface nocturnal activities only when outside temperatures are cool.

KEYWORDS: *Heterometrus fulvipes*, microclimate, temperature, thermister, stilting posture, hunting posture.

INTRODUCTION

It has long been known that animals living in burrows, crevices or underneath stones experience climatic conditions quite different from those of the macroenvironment. Such habitats protect the organism from climatic extremes which otherwise would be lethal. Cloudsley-Thompson (1962a, and 1962b) studied comprehensively on the microclimate and arthropod distribution of several desert species. The studies of Hadley (1970) established a correlation between the microclimatic parameters of the desert area and thermoregulatory activities of the scorpion *Hardrurus arizonensis*.

The present study has been designed to provide continuous data on environmental and burrow temperatures collected over a period of eight months covering the important seasons in an year. Concurrently, animal movements in the burrow during 24th of the day were observed.

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MATERIALS AND METHODS

The scorpion, *Heterometrus fulvipes* was used for the present investigation, as it is abundantly available in the field area located $1\frac{1}{2}$ Km away from the Sri Venkateswara University campus. Animals were collected after excaviting the burrows, brought to the laboratory and acclmatized to the burrows constructed in the laboratory.

The morphology of the burrows was studied by careful excavation and a model burrow was constructed in the field for studying the burrow temperatures. A glass-bead thermister mounted at one end of a flexible curtain wire, was used for measuring temperatures inside the burrow. The thermister was connected to a wheat-stone bridge and galvanometer. Concurrent measurements of the surface soil temperature near the burrow was made using a thermometer of 0.1° graduation. Recordings were made for every 2 hours in a 24 h day. Both environmental and burrow temperature measurements were recorded for every 12–15 days.

RESULTS

Environmental temperature:

Data collected from November 1988 to June 1989 is shown in Table 1. On clear days, the incoming solar radiation is smooth and symmetrical, reaching its maximum during 1 to 3 P.M. in all seasons of the year (Fig. 1a to c, Table 1). However, this maximum day temperatures showed more than one peak on rainy or cloudy days (Fig. 1b). Typically, the rise of temperature is rapid in the morning hours of the day, reaching its peak in about 5 to 7 hours. But the drop from peak to nadir is rather slow and it continues during the evening and even in the night hours of the solar day. Thus the minimal temperatures during 24 hours day, were recorded in the early morning hours prior to sunrise.

On warmest days, the maximal day temperatures recorded were 43.2°C in the month of May. During this period the minimal temperatures were around 32°C. Coolest day temperatures occured on rainy days, or in winter months (December to February). During this period maximal day temperatures were around 32°C, while the minimum recorded was around 20°C (Table 1).

Burrow temperature

On clear days, the rise of burrow temperatures (Fig. 1a to c) is also somewhat smooth and symmetrical and reaches its maximum either at the same time or one or two hours later compared to outside temperatures. This indicates a lag in conductive heat penetration during the day. But on rainy days (Fig. 2b), peak temperatures in burrows are recorded in the afternoons and even as late as 19.00 hrs in the evening. Peak temperatures are always lower by 1 to 8°C in burrows than outside peak temperatures. But minimal burrow temperatures are always higher by 1 to 6°C than outside temperatures. Thus scorpions living in burrows do not experience the highest and lowest temperatures existing outside the burrows.

TABLE 1 Environmental and burrow temperatures, recorded during the months of November to June covering the rainy and summer days in 1988–1989

Date/Time		7.00	9.00	11.00	13.00	15.00	17.00	19.00	21.00	23.00	1.00	3.00	5.00
28.11.88	ET	20.5	24.0	29.9	32.8	33.9	29.3	25.5	23.6	23.0	22.0	21.5	exit 21.2bg
bg o	BT	23.2	25.8	26.6	28.4	29.1	28.6	28.5	27.8	28.4	27.4	21.6	24.9
05.12.88	ET	24.6	27.9	31.0	35.5	30.2	27.2	26.6	26.8	26.5	26.6	26.6	25.0
•*	BT	27.7	27.3	27.2	28.2	28.9	30.8	29.7	28.3	29.2	26.5	25.7	26.5
19.12.88	ET	21.8	26.0	30.7	34.5	32.8	27.5	24.7	24.5	22.5	22.0	22.0	19.5
o	BT	27.5	27.4	27.8	28.4	29.1	29.5	29.7	29.5	28.5	28.2	28.0	27.2
25.12.88	ET	25.3	29.2	32.0	29.3	33.0	28.5	26.5	25.6	25.5	25.5	25.5	25.0
•*	BT	26.6	27.3	27.3	27.9	27.9	28.2	29.3	29.1	28.7	28.3	27.9	27.7
09.01.89	ET	20.3	25.3	32.0	32.0	30.5	28.4	24.6	23.5	21.5	21.0	22.0	22.0
o	BT	26.7	25.5	25.3	29.1	28.7	28.6	28.9	28.3	28.0	27.5	27.2	26.7
18.01.89	ET	22.0	27.3	29.5	33.9	32.3	29.0	25.8	24.7	23.7	23.2	22.2	21.3
o	BT	25.4	25.3	29.5	26.8	29.3	30.0	29.5	27.4	26.9	26.8	26.2	25.6
30.01.89	ET	22.0	26.5	33.0	32.4	32.8	29.3	25.3	24.7	24.0	23.5	22.7	22.6
o	BT	26.3	26.4	26.6	27.5	29.7	30.0	29.9	29.6	29.4	28.5	27.8	27.6
06.02.89	ET	21.1	28.4	32.3	32.5	33.2	29.2	24.8	24.4	23.7	21.2	21.0	19.5
o	BT	26.3	26.7	28.3	29.5	30.2	30.4	29.5	28.5	28.2	27.2	27.2	26.3

Contd

TABLE 1.Continues

Date/Time		7.00	9.00	11.00	13.00	15.00	17.00	19.00	21.00	23.00	1.00	3.00	5.00
12.02.89	ET	21.3	28.3	30.6	33.7	32.5	28.9	26.3	25.6	24.5	24.5	24.2	23.4
○	BT	26.8	26.9	27.4	28.1	28.8	31.1	30.7	30.0	29.1	27.8	27.3	26.8
01.03.89	ET	26.0	31.0	31.9	33.5	31.3	30.9	28.7	28.5	28.3	27.0	26.5	24.7
●*	BT	28.6	29.5	29.7	30.4	31.6	31.5	30.7	30.2	29.7	29.5	29.5	29.2
20.03.89	ET	28.8	32.8	37.9	37.5	36.9	33.5	30.3	29.8	24.5	28.8	28.8	28.8
○	BT	28.7	31.4	31.6	32.0	33.0	34.2	33.9	33.9	32.7	32.5	31.5	31.4
09.04.89	ET	29.1	33.5	37.5	36.5	36.6	34.5	30.4	29.8	29.5	29.3	28.5	28.3
●	BT	29.9	30.1	31.2	32.3	34.9	35.0	34.9	32.9	32.7	32.7	31.5	30.0
23.04.89	ET	27.5	34.5	38.5	38.6	37.2	33.5	30.5	30.5	30.5	30.0	29.4	28.3
○	BT	28.9	30.0	30.9	31.8	33.5	35.7	35.9	35.0	34.9	33.5	33.5	32.3
28.05.89	ET	34.5	38.2	39.6	43.2	43.2	38.5	35.0	33.5	32.6	32.6	32.2	31.5
○	BT	33.4	33.7	34.2	35.4	37.9	42.2	41.6	39.9	36.9	35.1	35.1	34.3
10.06.89	ET	32.4	36.5	37.5	40.5	39.5	39.5	37.0	34.5	33.9	32.5	31.7	30.3
○	BT	28.6	29.4	31.5	34.9	36.0	38.2	37.9	37.2	35.3	35.3	34.0	32.4

○-Clear day. ●-Cloudy day. ●*-Cloudy day with intermittent rains. ET-Environmental temperature. BT-Burrow temperature.

On a clear summer day, maximum burrow temperature (Table 1) recorded was 42.2°C (outside 43.2°C), while the minimum temperature obtained was 33.4°C (outside 31.5°C). On winter or rainy days, the maximum burrow temperatures were around 29 to 30°C (outside mostly 33°C), whereas the minimal temperatures were around 24 to 25°C (outside about 19°C).

Morphology of the scorpion burrows

The architecture of the burrows was studied by careful excavations and also by making castings. A typical burrow of an adult *Heterometrus fulvipes* has an oval entrance (2 cm width and 4 cm height) leading into a single tunnel (55 cm long) that makes several characteristic turns and finally ends in one adult scorpion. From the oval entrance, the burrow penetrates the ground at an average angle of 66° from the horizontal surface of the ground. Side tunnels or entrances were absent.

Daily behavioural activities in the burrow

Observations were made on the scorpion behaviour in the burrow constructed in a glass terraria in the laboratory. The scorpions rests during most part of the day (00.00 to 18.00 hrs) in the enlarged terminal chamber of the burrow. The animal shows signs of increased leg, tail and pedipalpal movements from about 18.00 h usually coinciding with the time of sunset. A little later the animal assumes the "stilting posture" i.e., it raises the body off the ground, erects the tail and spreads the pedipalps. In this posture the animal starts locomotor activity around 18.30 h. Thereafter, the animal slowly and cautiously walks a few centimeters, and then stands motionless for a brief period and again resumes walking towards the burrow entrance. The scorpion thus creeps through the burrow and often reaches the burrow entrance around 19.15 hrs (Fig. 2). At the burrow entrance, the scorpion displays a characteristic hunting posture, by hiding cephalothorax and post abdomen within the burrow, while projecting the ourstretched pedipalps out of the burrow entrance.

The predator in this posture remains motionless for even several hours. If undisturbed, the scorpion stands guard in this hunting posture at the entrance till about 24.00 hrs and then withdraws into the terminal chamber for the rest of the day.

Temperature tolerance

Survivability of *Heterometrus* at various higher temperatures as well as lower temperatures was studied by exposing them for 24 hours in temperature controlled chambers. For each temperature, two batches of animals, consisting of them in each were used. No mortality was observed in animals exposed to 35°C. Whereas higher temperatures of 40°C, 45°C and 50°C produced 25%, 90% and 100% mortality respectively within 24 hours. From the mortality data the LT_{50} value for warm temperature was found to be 42°C.

Similarly, the scorpions maintained in cool temperatures also showed mortality of 7% at 5°C, 70% at 0° and 100% at −5°C within 24 hours. The LT_{50} for cool temperatures was found to be −2.2°C.

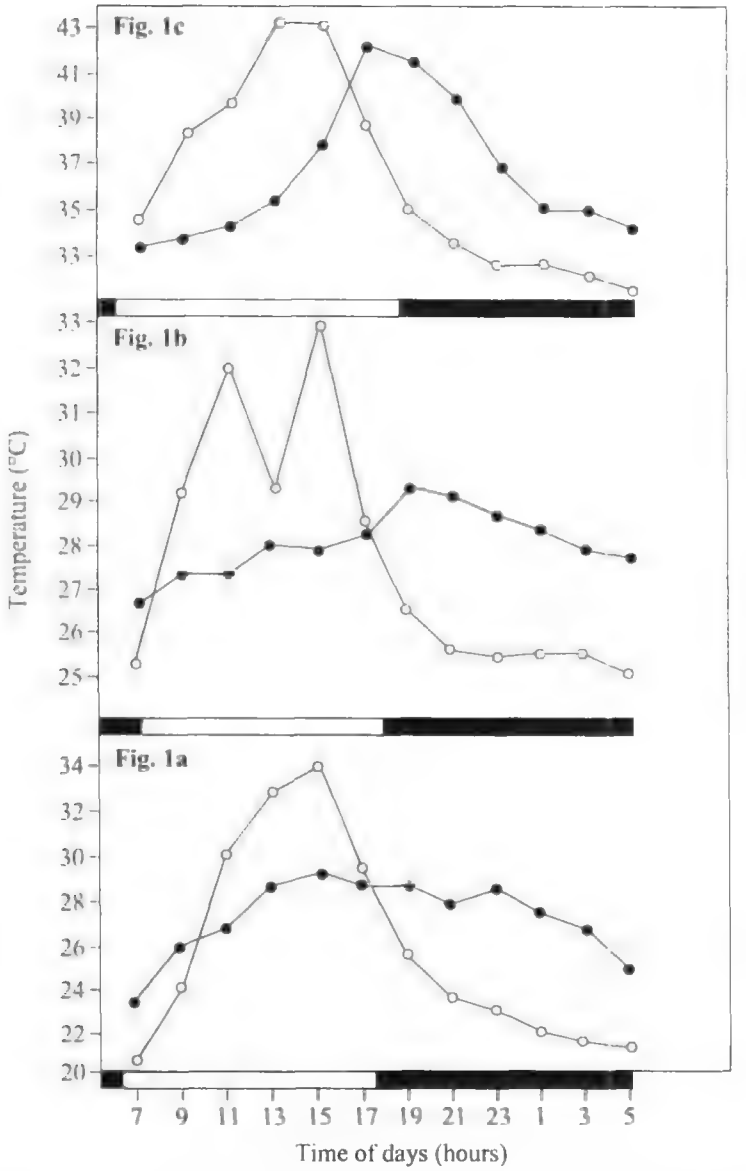

FIGURE 1. Environmental (o–o) and burrow (•–•) temperatures measured over a 24 hour period. (a) Temperature measurements on a winter day; (b) Temperature measurements on a rainy day; (c) Temperature measurements on warmest summer day.

DISCUSSION

Physical factors of the environment are of great ecological significance to animals living in the regions where the climatic changes between day and night are particu-

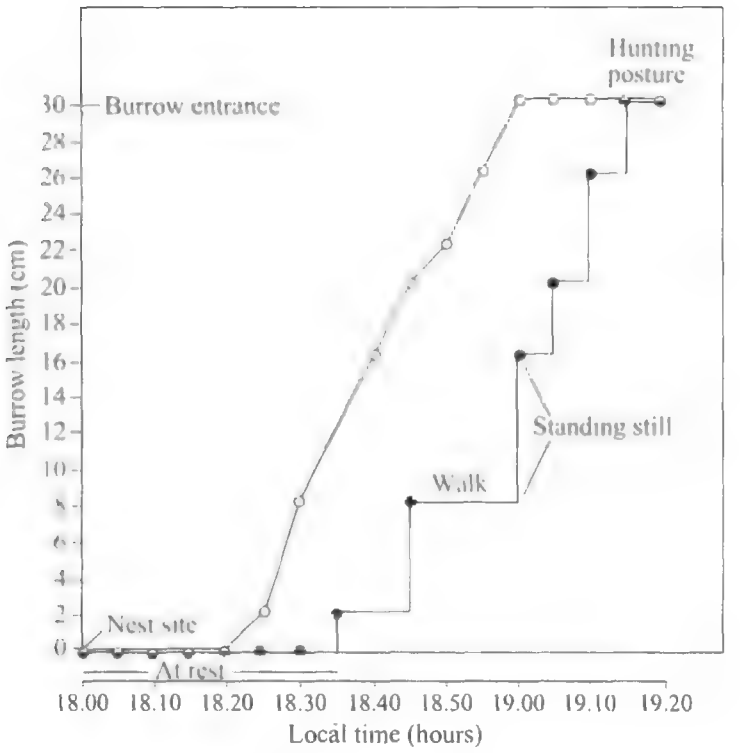

FIGURE 2. The sequence of *H. fulvipes* behaviour (•–•) in relation to the spread of zero-light level (o–o) in the model tunnel. The zero-light level is followed by animal locomotion with a delay 10–15 minutes. Scorpion displays hunting posture at about 19.15 h.

larly great (Cloudsley-Thompson, 1956). Under different conditions of temperature, humidity and light, scorpions manage to survive by their subterrarean habitat and nocturnal movements that provide a relatively constant and moderate environmental conditions (Williams, 1966; Hadley, 1970).

The scorpion, *H. fulvipes* also showed that the animal is subjected to a narrow range of temperature variations due to movements within and outside the burrow during 24 hours of the day. It means the scorpion actually moves from a warmer to a cooler environment.

The stilting posture that *Heterometrus* exbits at the terminal chamber and also at the mouth of the burrow is also considered to be an adaptation to temperature stress. This stilting of the abdoment was also observed for the South African scorpion *Ophisthopththalmus latimanus* which enhances the tolerance capacity of animal to high temperatures (Alexander and Ewer, 1958).

The ability of the scorpion to tolerate these high temperatures may be the result of preconditioning, since then burrow temperatures rise gradually taking several hours

to reach the peak level. According to Cloudsley-Thompson (1962) the scorpion *L. quinquestratus*, exhibit greater temperature tolerance during summer months resulting from seasonal acclimatization.

Responses to subfreezing conditions were also reported for the scorpion *Diplocentrus pelonicillensis* (Crawford and Riddle (1974, 1975)) which survives temperatures as low as −7°C. The environmental temperatures in which *H. fulvipes* lives, even-though the highest temperatures (43°C) are close to the lethal level, the minimal temperatures (19°) never touch the freezing level.

Thus, the scorpion, *H. fulvipes* escapes from temperature extremes by means of behavioural adaptations like burrowing, stilting and nocturnal surface activity.

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REFERENCES

Alexander, A. J. and Ewer, R. D. (1958) Temperature adaptive behaviour in the scorpion Opisthophthalmus latimanus Koch, *J. Exp. Biol.* **35**, 349–359.

Cloudsley-Thompson, J. L. (1956) Studies in diurnal rhythms VI. Bioclimatic observations in Tunisia and their significance in relation to the physiology of the fauna, especially woodlice, centipedes, scorpions and beetles, *Ann. Mag. Nat. Hist.* **9(12)**, 305–329.

Cloudsley-Thompson, J. L. (1962) Lethal temperatures of some desert arthropods and the mechanism of heat death, *Entomologia Exp. Appl.* **5**, 270–280.

Crawford, C. S. and Riddle, W. A. (1974) Cold hardness in centepedes and scorpions in New Mexico, *Oikos* **25**, 89–92.

Crawford, C. S. and Riddle, W. A. (1975) Overwintering physiology of the scorpion on *Diplocentrus spetzeri*, *Physiol. Zool.* **48**, 84–92.

Hadley, N. F. (1970) Micrometrology and energy exchange in two desert arthropods, *Ecol.* **51**, 434–444.

Riddle, W. A. and Pugach, S. (1976) Cold hardness in the scorpion, *Paruroctonus aquilonalis*, *Cryobiol.* **13**, 248–253.

Williams, S. C. (1966) Burrowing activities of the scorpion *Androctonus phaeodactylus* (Wood) (Scorpionida: Vaejovidae), *Proc. Calif. Acad. Sci.* **34**, 419–428.

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Efficacy of Controlled Release Polymer Formulations of Topical Repellents for Better Personal Protection Against Mosquito Bites

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ABSTRACT: Controlled release polymer formulations of three topical insect repellents viz. DEPA, DEET and DMP were evaluated for their efficacy against two vector mosquito species, *Anopheles stephensi* and *Aedes aegypti* in comparison with their respective repellent compounds in ethanol which were used as experimental controls. The polymer formulations of the three repellents generally showed better efficacy than the repellents in pure form with ethanol as base. DEPA-0 and DEET-0, as control repellents, showed more or less equal effectiveness on both rabbit skin and human skin against the two mosquito species at the rate of 0.5 mg/sq.cm, whereas DMP-0 was least effective in all respects. Of the four polymer formulations (A, B, D & E) of the repellents, B (Polymer I) and E (Polymer II) formulations of the three repellents exhibited better protection than the other two formulations. DEPA-B and DEET-B showed supremacy over DMP-B with longer pretection time (6.85–7.5 hr) at an application rate of 0.5 mg/sq.cm. DEET-B formulation displayed a maximum duration of protection for a period of 6.25–6.45 hrs on rabbit skin and 7.15–7.3 hr on human skin. In view of the findings of the present study, it is suggested that duration of protection offered by the repellents can be significantly extended through suitable and cosmetically acceptable polymeric formulations.

KEYWORDS: Topical repellents, controlled release formulations, DEET, DEPA, DMP, *Anopheles stephensi*, *Aedes aegypti*.

INTRODUCTION

Application of insect repellents, particularly mosquito repellents is the widely used method of personal protection to reduce man-vector contact and minimize the transmission of vector borne diseases. The dangers and problems met with indiscriminate

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use of potent synthetic organic insecticides have brought renewed efforts for the development of better repellents. From the standpoint of ecology, repellents might well be the method of choice because the comfort and welfare of the subject is achieved while ecosystems are left undisturbed. The effectiveness of some topical repellents such as DEET, DEPA, DMP and toluacetamides in giving protection against mosquito bites has been established (Zhoglov, 1968; Kalyanasundaram, 1982; Santhosh Kumar *et al.*, 1984; Skider *et al.*, 1994).

Recently the emphasis has been on new slow or sustained release formulations to make the repellent more active, cosmetically acceptable and easier to apply. Acrylic polymers, silicon and polysaccharides were used for formulation to improve the effectiveness of the repellents (Khan, 1967). It was found that polymer formulation of DEET protected longer (24 hr) than when DEET alone was applied (12–16 hr) at the application rate of 1.6 mg/cm^2 (Khan *et al.*, 1976). A polymer formulation and two microcapsule formulations of DEET provided more than 80% protection for 12 hr (Mehr *et al.*, 1985). Vanishing cream formulation of DEET was found to give protection for 6–7 hr at 0.5 mg/cm^2 (Khan *et al.*, 1975a). Several other studies also indicate that the protection time of repellents can be extended through controlled release formulations (Khan *et al.*, 1975a; Prasad and Kalyanasundaram, 1990; Mani *et al.*, 1991).

In the present study comparative efficacy of the controlled release polymer formulations of three topical insect repellents DEPA, DEET and DMP was studied for personal protection against a malaria vector, *Anopheles stephensi* and a dengue vector, *Aedes aegytpi*.

MATERIALS AND METHODS

Repellents

Three repellents viz. N,N-diethylphenyl acetamide (DEPA), N,N-diethyl *m*-toluamide (DEET), Dimethyl phthalate (DMP) were utilized for making different polymer formulations. Polymer formulations were prepared and provided by the Insecticide-Chemistry Division of Vector Control Research Centre (VCRC).

Polymer Formulations

The formulations of the repellents were made with the pharmacologically safe and hydrophilic polymer additives (I) & (II) and ethanol was used as the solvent. 5% and 10% concentrations were made with both polymer I and polymer II, and named as A & B respectively for the former and D & E for the latter. Each repellent at a concentration of 20% in ethanol was used as control and named as DEPA-O, DEET-O and DMP-O (Fig. 1).

Testing on Rabbit Skin

The test method was modified from that of Bar-Zeev and Ben-Tomar (1971). Six month old rabbits weighing 1.0 to 1.7 kg were used for all the tests. The lateral portion

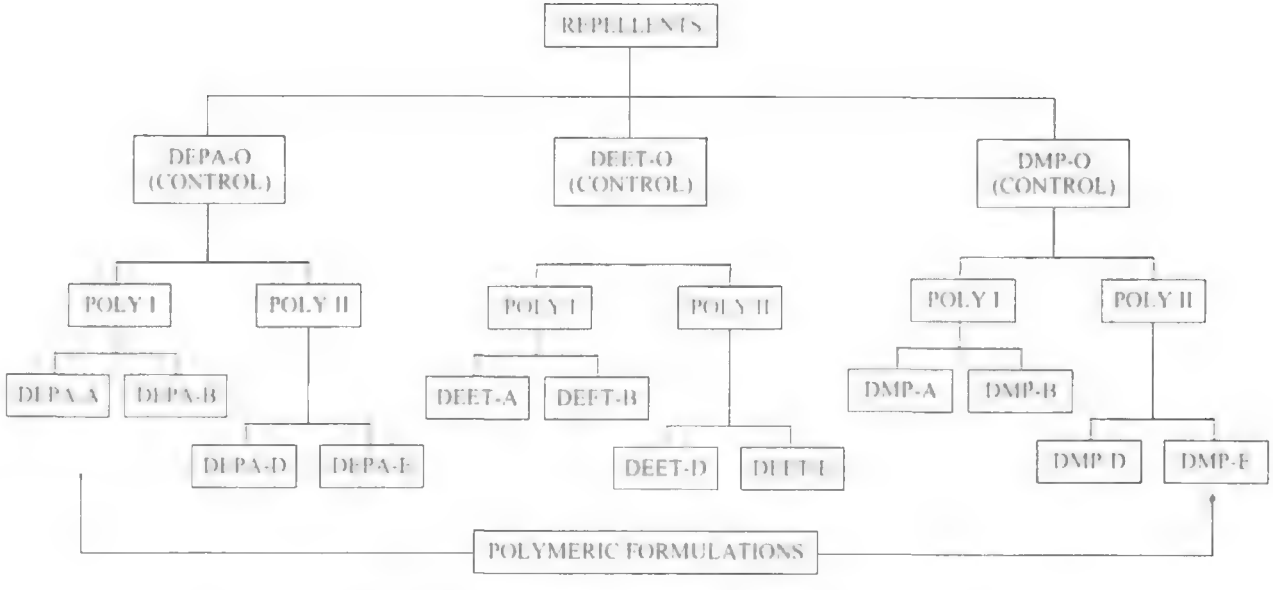

FIGURE 1. Repellents and their respective polymericformulations used in this study

of the belly of the rabbit was shaved to remove the hairs from the measured area of 50 cm^2 for the application of the repellent. Before applying the repellent the rabbit was introduced into the mosquito colony cage to ensure that mosquitoes were hungry and can feed readily on the shaved portion. The repellents were applied uniformly on the shaved portion at two application rates of 0.25 and 0.5 mg/cm^2. After application of the repellent, the rabbits were confined in a restrainer cage and the cage was covered with thick cotton cloth exposing only the repellent applied portion.

The restrainer cage was then introduced into the mosquito colony cage for 2 min and observed for biting on the treated area. The testing was repeated at 30 min intervals until the first bite on the treated area was noted which was taken as the protection time (PT) for any given formulation at the given rate of application. The test was repeated five times for each rate of application.

Testing on human volunteers

The formulations which gave higher protection time than the control repellents when tested on rabbit skin, were applied on human skin and the efficacy of the formulations was determined. The repellent formulations such as DEPA-B, DEPA-E, DEET-B, DEET-E, DMP-B and DMP-E were applied on the contralateral portion of the forearm at an application rate of 0.5 mg/cm^2. The test method was modified from that of Khan *et al.* (1975b). After application of the repellent on the forearm the gloves were pulled over and held in position thus exposing only the treated area and it was introduced into the colony cage for two minutes and observed for biting on the treated area. The testing was continued at 30 min. intervals until the first bite on the treated area was noted and recorded as the protection time for that formulation. Each test was repeated for five times for each rate of application.

All tests were carried out in a room at $27 + 2°C$ and $75 \pm 5\%$ RH. The testing period was 06.00–14.00 hr for *Ae. aegypti* and 18.00–02.00 hr for *An. stephensi*. Percentage increase in protection time (%IPT) of the polymer formulations with respect to each control repellent was calculated as:

$$\text{Percentage increase in protection time (\%IPT)} = \frac{(T - C)}{C} \times 100$$

where T is the protection time of the polymer formulation and C is the protection time of the control formulation without any polymer additive. The testing was carried out at $27 \pm 2°C$ with relative humidity ranging from 70–80%.

Statistical Analysis

Comparison of the protection time of different formulations was carried out by two way analysis of variance (ANOVA) (Sokal and Rohlf, 1981), which allowed all possible comparisons between experimental groups.

RESULTS

Efficacy of repellent compounds used as control

When comparing the repellency of the three control repellents (DEPA-0, DEET-0 and DMP-0) on rabbit skin, analysis of variance (ANOVA) revealed that the protection time observed for each control repellent was significantly ($P < 0.05$) different at two different application rates of 0.25 and 0.5 mg/cm^2 against the two mosquito species except DEPA-0 against *An. stephensi*. DEPA-0 and DEET-0 were found to give longer protection than DMP-0.

The three control repellents were studied for their repellency on human skin at the application rate of 0.5 mg/cm^2 against *Ae. aegypti* and *An. stephensi*. On comparison, it was found that DEPA-0 and DEET-0 were equally effective against both the mosquito species, giving a mean protection time ranging from 4.9 to 5.05 hrs. DMP was found to be the least effective one against both mosquito species giving a mean protection time of only 2.75–3.25 hours.

Efficacy of Polymer Formulations of Repellents

Protection time was observed for four polymer formulations (A & B of polymer I and D & E of polymer II) of each repellent at the application rates of 0.25 and 0.5 mg/cm^2 on rabbit skin against both the mosquito species. The results showed that all polymer formulations of the repellents generally exhibited higher protection than the control repellents (Fig. 2–4).

Efficacy of Polymer Formulations of DEPA

Of the four polymer formulations, DEPA-B showed better protection for 3.75–6.75 hr with maximum increase in protection time (34–37%) followed by DEPA-E (21–24%) against *Ae. aegypti* and *An. stephensi* at both application rates of 0.25 and 0.5 mg/cm^2. However, the other two formulations (DEPA-A & DEPA-D) did not give appreciable increase in protection time (5–8%) against the same species at both application rates (Fig. 2a & b).

Efficacy of Polymer Formulations of DEET

Among the four formulations, DEET-B gave maximum protection for a period of 4.5–5.6 hr at 0.25 mg/cm^2 and 6.25–6.45 hr at 0.5 mg/cm^2 against the two species. Percentage increase in protection time of DEET-B ranged between 35.79–67.16 whereas for the other formulations (A, D & E) it ranged from 8.96–38.81 against the two species at both the application rates (Fig. 3a & b).

Efficacy of Polymer Formulations of DMP

Generally the protection time obtained for DMP formulations was comparatively lesser than that obtained for the formulations of other two repellents. However, while comparing with control repellent (DMP-0), DMP-B provided higher protection than the other formulations for a duration of 2.35–3.45 hr with corresponding increase in

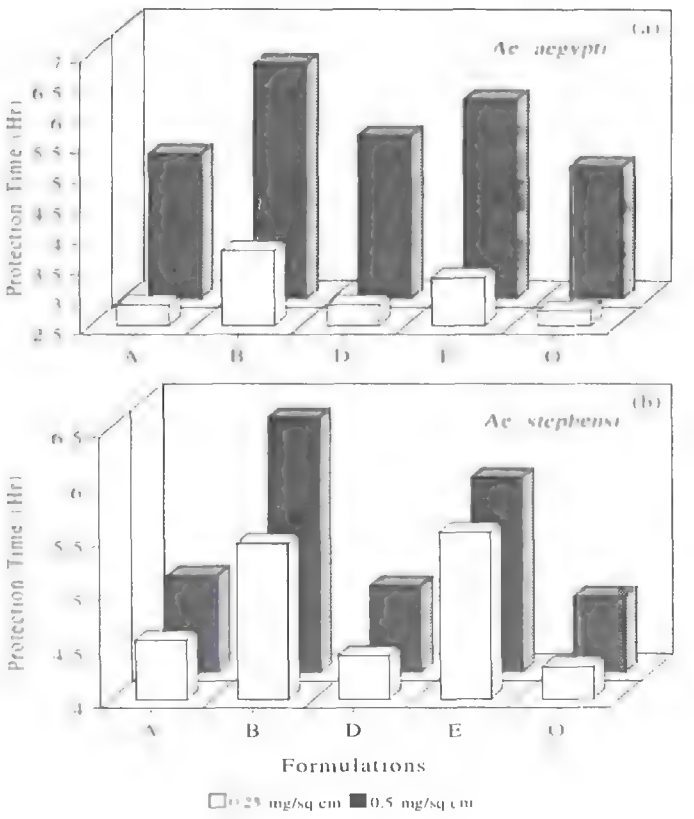

FIGURE 2. Comparative efficacy of DEPA formulations against (a) *Ae. aegypti* and (b) *An. stephensi*.

protection time of 50.0–80.77% at both application rates against these vectors (4a & b).

Efficacy of the polymer formulations on human volunteers

When B & E formulations of the three repellents were applied on human skin at the rate of 0.5 mg/sqcm, DEET-B gave maximum protection for a period of 7.15 and 7.3 hr against *Ae. aegypti* and *An. stephensi* respectively (Fig. 5a & b). Better personal protection against both species was offered by the following other formulations in the order of their effectiveness: DEPA-B>DEET-E>DEPA-E>DMP-B> DMP-E.

From this study it was found that formulations of the three repellents prepared by adding 10% of the polymer I (B) was significantly ($P < 0.05$) more effective than

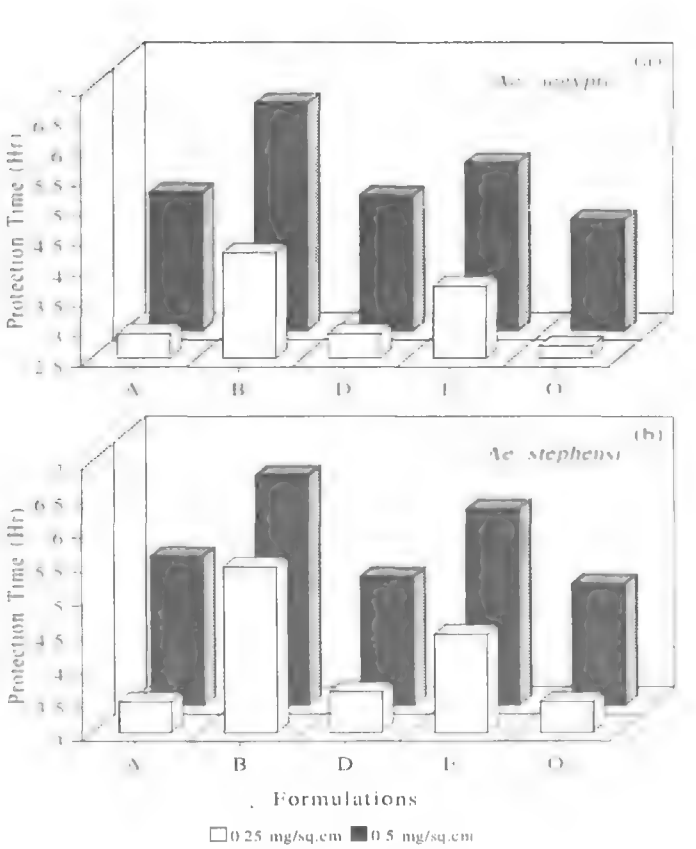

FIGURE 3. Comparative efficacy of DEET formulations against (a) *Ae. aegypti* and (b) *An. stephensi*.

the other formulations when applied at the rate of 0.5 mg/cm^2 on rabbit skin. Similar efficacy was observed for the same formulations while tested on human volunteers.

DISCUSSION

Present study showed that among the three control repellents, DEPA-0 and DEET-0 gave more or less equal repellency at the application rate of 0.5 mg/cm^2 on rabbit skin with longer protection time against the bites of *Ae. aegypti* and *An. stephensi* when compared to DMP-0. Earlier studies on these repellents have also indicated longer protection time against *Cx. quinquefasciatus* for 6.75–7.0 hr (Santhosh Kumar *et al.*, 1984) and *Ae. vexans* and *Ae. caspius* for 8.0–9.0 hr (Zhoglov, 1968).

In this study, DEPA-0 demonstrated an increased protection time against *Ae. aegypti* at increased application rate (0.5 mg/sq.cm) as also observed in other studies on

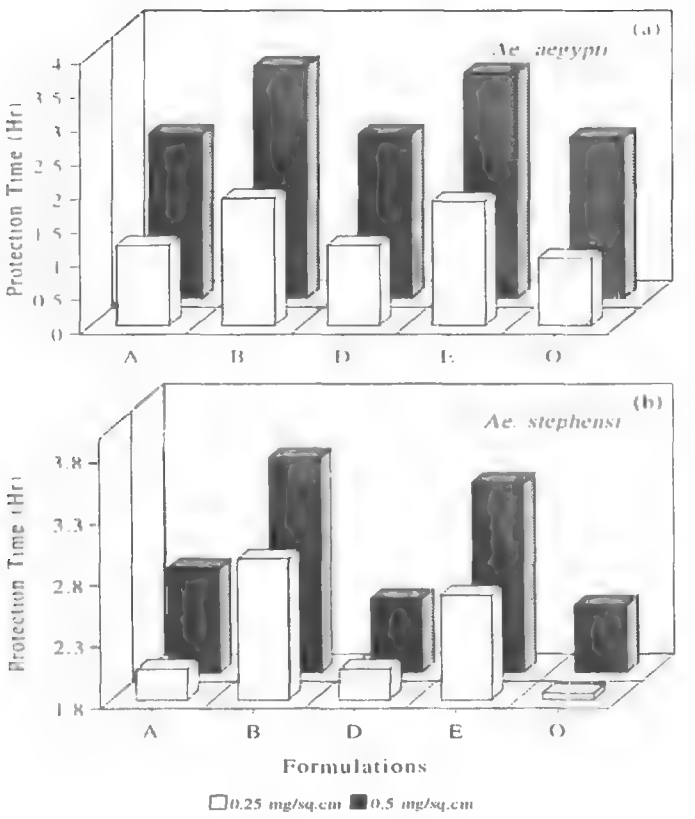

FIGURE 4. Comparative efficacy of DMP formulations against (a) *Ae. aegypti* and (b) *An. stephensi*.

Xenopsylla cheopis and *Phlebotomus papatasi* (Mathur *et al.*, 1986; Kalyanasundaram *et al.*, 1994). However, no significant increase could be observed in the protection time against *An. stephensi* by increasing the rate of application. This suggests that increase in application rate will not always result in better protection time against different target species.

Comparative Efficacy of Polymer Formulations

While comparing with the control repellents, the polymer formulations irrespective of their concentration exhibited improved protection time on rabbit skin. In addition, the concentration of the polymer was also found to influence the protection time. Among the polymer (5% & 10%) formulations, DEPA-B, DEET-B and DMP-B offered significantly ($P < 0.05$) longer protection time against *Ae. aegypti* and *An. stephensi*

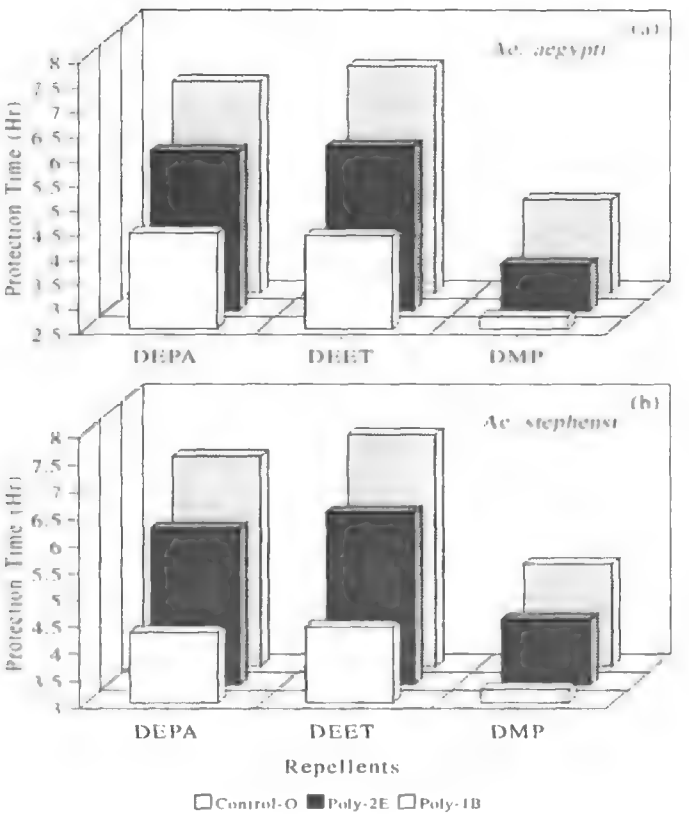

FIGURE 5. Comparative efficacy of polymer formulations (B & E) of the three repellents against (a) *Ae. aegypti* and (b) *An. stephensi*.

than other formulations (A, D & E). Similarly, increase in the protection time of the polymer formulation of DEPA and DEET against *Ae. aegypti* has been reported (Khan *et al.*, 1975b; Mehr *et al.*, 1985). The possible explanation for this is that the polymer physically binds the repellent molecule and minimizes the loss of the repellent by normal evaporation and percutaneous absorption thereby extending the protection time (Prasad and Kalyanasundaram, 1990).

In contrast, Spencer *et al.* (1977) could observe no significant difference in protection time of control and polymer formulations of DEET against *Ae. aegypti*. Later, a formulation of DEET:VANILLIN at different ratios showed an increased protection time by 95%–176% (Khan *et al.*, 1975b). In subsequent studies increase in protection time by 80% against *Ae. aegypti* has also been reported for microencapsulated, polymer and other formulations of DEET which indicated improved protection time of the for-

mulated repellents through controlled release technology (Mehr *et al.*, 1985; Schreck and Kline, 1989).

Polymer formulations of the three topical repellents tested on human skin demonstrated better protection against two vector mosquitoes when compared to their respective control. Among the B formulations of the three repellents, DEET-B was the most effective formulation followed by DEPA-B for longer personal protection.

The present study signifies the potentiality of repellents when they are formulated with suitable polymer additives in extending the duration of protection against the bites of some vector mosquito species.

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REFERENCES

Bar-Zeev, M. and Ben-Tomar, D. (1971) Evaluation of mosquito repellents, *Mosq. News* **31**, 56–61.

Kalyanasundaram, M. (1982) A preliminary report on the synthesis and testing of mosquito repellents, *Indian J. Med. Res.* **76**, 190–194.

Kalyanasundaram, M., Srinivasan, R., Subramanian, S. and Panicker, K. N. (1994) Relative potency of DEPA as a repellent against the sand fly *Phlebotomus paptasi*, *Med. Vet. Entomol.* **8**, 68–70.

Khan, A. A. and (1967) Mosquito attractants and repellents, In: *Chemical control of insect behaviour: Theory and application*, Shorey,; McKelvery Jr, H. H ; John Wiley and Sons: U.S.A., 305.

Khan, A. A., Maibch, H. I. and Skidmore, D. L. (1975a) Insect repellents; Effect of mosquito and repellent related factors on protection time, *J. Eco. Entomol* **68**, 43–45.

Khan, A. A., Maibch, H. I. and Skidmore, D. L. (1975b) Addition of Vanillin to mosquito repellents to increase protection time, *Mosq. News* **35**, 223–225.

Khan, A. A., Maibch, H. I. and Skidmore, D. L. (1976) Polymer to increase abrasion and water wash resistance of mosquito repellents, *Mosquito News* **36**, 67–75.

Mani, T. R., Rueben, R. and Akiyamma, J. (1991) Field efficacy of "Mosbar", mosquito repellent soap against vectors of Bancroftian Filariasis and Japanese encephalitis in southern India, *J. Am. Mosq. Control Assoc.* **7**, 565–568.

Mathur, K. M., Gupta, G. P., Kaushik, M. I., Sikdhar, A. K. and Rao, K. M. Laboratory evaluation of Diethyl phenyl acetamide and other insect repellents against Rat flea.

Mehr, Z. A., Rutledge, L. C., Morales, E. L., Meixsell, V. E. and Korte, D. W. (1985) Laboratory evaluation of controlled release repellent formulations, *J. Am. Mosq. Control Assoc.* **1**, 143–147.

Prasad, M. P. and Kalyanasundaram, M. (1990) Development and evaluation of controlled release formulations of DEPA an insect repellent, *Indian J. Med. Res.* **(A)91**, 453–457.

Santhosh Kumar,, Shri Prakash,, Sharma, R. K., Jain, S. K., Kalyanasundaram, M., Swamy, R. V. and Rao, K. M. (1984) Field evaluation of three repellents against Mosquitoes, Black flies and Land leeches, *Indian J. Med. Res.* **80**, 541–545.

Schreck, C. E. and Kline, D. L. (1989) Repellency of two controlled release formulations of DEET against *Anopheles quadrimaculatus* and *Aedes taeniorhynchus* mosquitoes, *J. Am. Mosq. Control Assoc.* **5**, 91–94.

Skider, N., Gopalan, N., Shri Prakash., Vinod, V. K., Rao, S. S. and Rao, K. M. (1994) Mosquito repellency and toxicity of isomeric N,N-diethyl tolyacetamide. *Indian J. Med. Res.* **99**. 121–123.

Sokal, R. R. and Rohlf, J. F. (1981) Biometry principles and Practice of statistics in Biological Research, 2nd Ed., W. H. Creeman & Co.: New York. pp. 445.

Spencer, T. S., Hill, J. A., Akers, W. A. and Bjarkland, G. (1977) Studies on repellent formulation with N,N-diethyl-*m*-toluamide, Army Institute of Research, San francisco: California 94129, USA, 121–123.

Zhoglov, D. T. (1968) On the sensitivity to repellents of *Anpheles pulcherimus* (Theobald) and some other species of mosquitoes, *Medskaya Parasitològia* **37**, 493–495.

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Biochemical Modulations by Insecticides in a Non-target Harpactorine Reduviid *Rhynocoris kumarii* Ambrose and Livingstone (Heteroptera : Reduviidae)

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ABSTRACT: Changes in the organic constituents, such as, the carbohydrates, proteins, lipid, dry matter and water content in the alimentary canal and entire animal of *Rhynocoris kumarii* Ambrose and Livingstone by five commonly used insecticides in the cotton agroecosystem namely monocrotophos, dimethoate, methylparathion, quinalphos and endosulfan were studied. All of the insecticides reduced carbohydrates and proteins and increased lipids in the alimentary canal as well as in the entire animal. Dry matter was decreased by the insecticides except endosulfan. On the contrary water content was increased by the insecticides except endosulfan.

KEYWORDS: *Rhynocoris kumarii*, insecticides, organic constituents.

INTRODUCTION

Biological control of insect pests as a part of IPM has been gaining momentum since it is specific; safer to non-target species, beneficial insects, higher animals and man and environmental friendly (Jeyaraj, 1992). Among entomophagous insects, predatory reduviids are identified as potential insect predators in several agroecosystems (Cohen, 1990; James, 1994; Ambrose, 1996). Many insecticides when used in different ecosystems not only affected the pest population but also produce deleterious effect on the non-target natural enemies. Hence screening of insecticides is imperative to safeguard the non-target beneficials. Information on the impact of insecticides on non-target beneficials is imperative for the researchers as well as the farmers to select the most suitable insecticide(s) with least damage to beneficials like *R. kumarii*. Although insecticides are evaluated for their control potential against particular insect pests, their impact on biology and physiology of non-target beneficials is being neglected. This prompted the authors to study the impact of sublethal concentration of the commonly used insecticides viz., monocrotophos, dimethoate, methylparathion, quinalphos and endosulfan in cotton agroecosystems on the organic constituents, such

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as, the carbohydrates, proteins, lipids, dry matter and water content of the reduviid predator *Rhynocoris kumarii* Ambrose and Livingstone. *R. kumarii* was reported as a potential predator on various insect pests viz., *Helicoverpa armigera* Hubner, *Dysdercus cingulatus* Fabricius, *Mylabris pustulata* Thunberg, *Earias insulana, Boisdual Spodoptera litura* Fabricius and *Corcyra cephalonica* Stainton (Ambrose, 1999).

MATERIALS AND METHODS

Adults of *R. kumarii* were collected from agroecosystems bordering Marunthuvazhmalai scrub jungle a legendary hillock in Kanyakumari District, Tamil Nadu, South India (altitude 50±5.77 mts; latitude 77° 35′E and 8° 14′N). They were maintained in laboratory in plastic containers (80 ml) at 30±2°C, RH ranging from 75–80% and photoperiod between 11–13 hrs on *C. cephalonica*. Preliminary studies were conducted with each insecticide to find out LC_{50} concentration of the adult insects for 48 hr. duration and 1/10 values of the 48 hr. LC_{50} concentration of each insecticide were considered as the sublethal concentrations. They were 0.0068, 0.0094, 0.0028, 0.0082 and 0.0170% for monocrotophos, dimethoate, methylparathion, quinalphos and endosulfan, respectively.

Cotton leaves were cut to the size of containers and the sublethal concentration of each insecticide was sprayed over such cut leaves, separately using hand sprayer. Sprayed leaves were dried for about 10 minutes under ceiling fan and placed over moist tissue paper to keep them turgid in fresh container. Three such leaves were placed inside each container with the ventral surface of leaves facing upwards (Nagia *et al.*, 1990). Twenty, 5 to 10 days old males and females (10 each) were exposed to the sublethal dosage of each insecticide, separately. A control set up was maintained with 10 adult *R. kumarii* and they were exposed to water sprayed cotton leaves. The experimental as well as control individuals were maintained at room temperature (29± 1°C). The concentration of the insecticide was maintained continuously for 10 days. i.e. each day the insecticide sprayed leaves were replaced with fresh insecticide sprayed leaves. The twenty experimental insects of each insecticide category was further divided into 2 sets, 10 each for total and alimentary canal biochemical estimations, separately. Total carbohydrate was estimated by anthrone reagent method (Carroll *et al.*, 1956); total protein by Lowry method (Lowry *et al.*, 1951) and total lipids by soxhelet method (AOAC, 1970). Dry matter and water content of the alimentary canal and entire animal were estimated gravimetrically. Biochemical variations in carbohydrates, proteins, lipids, dry matter and water content quantities due to insecticidal exposure were first analysed by one way analysis of variance (SAS Institute, 1988) to determine if differences existed among treatment means. When significant differences among treatment means were found the differences between individual treatment means were tested by Tukey multiple comparison test (Tukey, 1953). Statistical significance was determined by setting the aggregate type I error at 5% ($P < 0.05$) for each set of comparisons.

RESULTS AND DISCUSSIONS

Biochemical variations due to the sublethal concentration of all of the five insecticides in total carbohydrates, proteins, lipids, dry matter and water content in the alimentary canal and entire animal of *R. kumarii* are presented in tables 1 and 2. Alimentary canal carbohydrate content of normal *R. kumarii* (16.833 ± 2.858) mg/g) was reduced by insecticides except quinalphos which increased to 17.000 ± 2.529 mg/g. Maximum reduction was caused by methylparathion (7.833 ± 2.483 mg/g) (Table 1). Insecticides also reduced total carbohydrate content in entire animal. Methylparathion caused the highest reduction ie, reduced the carbohydrate content from normal 11.833 ± 2.483 to 6.000 ± 1.673 mg/g (Table 2). Reduction in carbohydrate content could be attributed to its higher utilization warranted by altered metabolism due to insecticidal toxic stress. Such high energy demands for various endothermic biochemical reactions can be readily met from the carbohydrate reserves because they are the principal and immediate energy precursors. Such observations along with the correlation between the levels of toxicity of insecticides and reduction in carbohydrate were reported by Mansingh (1972) and Reddy and Rao (1982). Maximum reduction of carbohydrate by methylparathion is correlated to its highest toxicity as observed by Ahamed *et al.* (1978), Chockalingam *et al.* (1988) and Machale *et al.* (1991).

Insecticides reduced total proteins in the alimentary canal as well as in the entire animal. The highest reduction was caused by the methylparathion (193.333 ± 25.835 to 125.500 ± 12.161 mg/g) in the alimentary canal. Insecticidal reduction of total proteins in the alimentary canal as well as in the entire animal could be attributed to the continued high energy demand, especially after the depletion of carbohydrate (glycogen) reserves. Moreover, prolonged insecticidal stress could reduce the synthesis of protein by deranging the protein synthetic machinery (Bharathi and Govindappa, 1987a,b). They further attributed insecticidal reduction of protein content in the gut to the active entry of insecticides into the haemolymph. Besides, the histopathological changes in the intestinal walls causing proteolysis of the tissue could lead to decreased protein content. Similar observations were reported by Maheswari and Sehgal (1981), Reddy and Rao (1982), Chockalingam *et al.* (1988) and Machale *et al.* (1991).

Lipid content in the alimentary canal and in the entire animal was increased by insecticides. Maximum increase caused by methylparathion was from 279.833 ± 32.896 and 294.333 ± 31.386 mg/g (normal) to 345.833 ± 26.656 mg/g and 374.667 ± 37.452 mg/g, respectively. Insecticides increased the lipid content to offer a protective mechanism to prevent further entry of insecticides (Weismann, 1955). A similar observation was reported by George (1996) in two other sister harpactorine reduviids *Rhynocoris fuscipes* (Fabricius) and *R. marginatus* (Fabricius). Weismann and Reiff (1956) further reported that DDT exposed *Musca domestica* Linn. contained more lipid in the tarsi, the normal site of entry of insecticides than normal houseflies. Munson *et al.* (1954) stated that the insects resistant to insecticides had a higher lipid content than insects which are

TABLE 1. Effect of sublethal concentration (1/10 of 48 hr LC_{50}) of five insecticides on the total carbohydrates (mg/g wet weight) total proteins (mg/g wet weight), total lipids (mg/g dry weight) dry matter (mg/g wet wt.) and water content (%) in the alimentary canal of *R. kumarii* ($n = 6$; $\bar{x} \pm$ SD)

Insecticides	Carbohydrates	Proteins	Lipids	Dry matter	Water content
Control	16.833 ± 2.858^{a}	193.833 ± 25.835^{a}	$279.833 \pm 32\,896^{cd}$	185.415 ± 15.032^{ab}	81.459 ± 1.503^{b}
Monocrotophos	11.500 ± 3.802^{bcd}	$126\,833 \pm 8.208^{b}$	$327\,167 \pm 16.714^{ab}$	$153\,181 \pm 8\,425^{cd}$	$84\,682 \pm 0\,842^{acd}$
Dimethoate	15.333 ± 2.805^{ac}	134.000 ± 10.119^{b}	309.500 ± 18.042^{ac}	174.225 ± 10.614^{b}	83.411 ± 2.267^{bc}
Methylparathion	$7\,833 \pm 2.483^{d}$	$125\,500 \pm 12.161^{b}$	$345\,833 \pm 26\,656^{a}$	$145\,372 \pm 8\,789^{d}$	$85\,643 \pm 0.879^{acd}$
Quinalphos	17.000 ± 2.529^{a}	145.500 ± 14.251^{b}	$302\,333 \pm 25\,997^{ad}$	$166\,617 \pm 13.769^{bc}$	$83\,338 \pm 1\,377^{bd}$
Endosulfan	15.833 ± 3.869^{ab}	$178\,167 \pm 20\,024^{a}$	$290\,333 \pm 28\,388^{bcd}$	$203\,441 \pm 12\,852^{a}$	$80\,072 \pm 0\,733^{ab}$

*Means carrying same alphabet in a column are not significantly different at 5% ($p > 0.05$) by Tukey test

TABLE 2. Effect of sublethal concentration (1/10 of 48 hr LC_{50}) of five insecticides on the total carbohydrates (mg/g wet weight) total proteins (mg/g wet weight), total lipids (mg/g dry weight) dry matter (mg/g wet wt.) and water content (%) in the entire *R. kumarii* ($n = 6$; $\bar{x} \pm$ SD).

Insecticides	Carbohydrates	Proteins	Lipids	Dry matter	Water content
Control	11.833 ± 2.483^{a}	225.167 ± 33.475^{a}	294.333 ± 31.386^{bcd}	237.819 ± 22.115^{ab}	76.133 ± 2.108^{de}
Monocrotophos	$6.667 \pm 2\,066^{b}$	$169\,333 \pm 12.258^{cd}$	$374\,667 \pm 37\,452^{ab}$	$188\,100 \pm 10\,340^{de}$	$81\,190 \pm 1.034^{ab}$
Dimethoate	$9\,667 \pm 1\,633^{ab}$	175.333 ± 12.258^{bd}	$317\,667 \pm 35\,132^{ad}$	222.898 ± 20.702^{bc}	77.710 ± 2.070^{cd}
Methylparathion	$6.000 \pm 1\,673^{b}$	$153\,833 \pm 13\,833^{d}$	$370\,000 \pm 25\,799^{a}$	$176.271 \pm 11\,274^{e}$	$82\,373 \pm 1\,127^{a}$
Quinalphos	$11\,500 \pm 2\,168^{a}$	$187\,667 \pm 12.011^{bc}$	329.000 ± 35.660^{ac}	$207.714 \pm 12\,411^{cd}$	$79\,228 \pm 1\,241^{bc}$
Endosulfan	$11\,733 \pm 2\,639^{a}$	206.167 ± 23.634^{ab}	$301\,500 \pm 38\,313^{bcd}$	$257\,122 \pm 9\,840^{a}$	$74\,288 \pm 0\,984^{e}$

*Means carrying same alphabet in a column are not significantly different at 5% ($p > 0.05$) by Tukey test

susceptible. Neri *et al.* (1958) confirmed this observation and stated that the resistant *Anopheles atroparvus* contained 64% more lipid than sensitive ones. The highest lipid content in methylparathion and monocrotophos treated *R. kumarii* is hence attributed to the higher resistance developed by the predator.

Both in the alimentary canal and in the entire animal, the dry matter content was reduced by all of the insecticides except endosulfan, which increased. On the contrary, alimentary canal and entire animal water contents were increased by the insecticides except endosulfan, which decreased the water content. The increase in the water content with decrease in the dry matter by the insecticides could be attributed to less water loss through transpiration and faeces (Delvi and Pandian, 1971; Pandian *et al.*, 1978; Naik and Delvi, 1984). This reduction in water loss through transpiration might be facilitated by the increased lipid content of the body. Insecticide treated *R. kumarii* might have also utilized less quantity of water as reported by Srinivasan (1977) in *M. domestica* larvae. Meagre increase in the lipid content of *R. kumarii* was not sufficient to protect the water loss through transpiration and faeces. Hence endosulfan treated *R. kumarii* had decreased the water content both in the alimentary canal and in the entire animal.

The studies suggest that these commonly used insecticides namely, monocrotophos, dimethoate, methylparathion, quinalphos and endosulfan in the agroecosystems could affect the physiology of non-target reduviid predator *R. kumarii* which preys upon insect pests. Hence screening of insecticides is imperative to safeguard the non-target beneficials, such as *R. kumarii*.

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REFERENCES

Ahamed, I. K., Begum, M. R., Sivaiah, S. and Rao, K. V. R. (1978) Effect of malathion on free aminoacids, total proteins, glycogen and some enzymes of pelecypod *Lamellidens marginallis* Lamarck, *Proc. Indian Acad. Sci. (Anim. Sci.)*, **87(12)**, 377–380.

Ambrose, D. P. (1996) *Assassin bugs (Insecta-Heteroptera-Reduviidae) in biocontrol: Success and strategies, a review; in, Biological and Cultural Control of insect pests, an Indian scenario*. Ambrose,; Adeline Publishers: Tirunelveli, pp. 262–284.

Ambrose, D. P. (1999) *Assassin Bugs*, Oxford & IBH Publishing Co. Ltd.: New Delhi, pp. 337.

AOAC, (1970) Official methods of analysis of the association of official analytical chemists. AOAC: Washington, DC, pp. 1015.

Bharathi, D. and Govindappa, S. (1987a) Effect of carbaryl on the organic constituents in the gut region of the blister beetle *Mylabris pustulata*, *Environment & Ecology* **5(1)**, 56–59.

Bharathi, D. and Govindappa, S. (1987b) Effect of carbaryl on the organic constituents of hemolymph of blister beetle *Mylabris pustulata*, *Environment & Ecology* **5(1)**, 65–70.

Carroll, N. V., Longley, R. W. and Roe, J. H. (1956) Glycogen determination in liver and muscle by use of anthrone reagent, *J. Biol. Chem.* **220**, 583–593.

Chockalingam, S., Jeyachandran, K. P. S. and Shanthy, B. (1988) Effect of sublethal concentrations of dairy effluent on the biochemical constituents in the nymphs of dragon fly *Brachythermis contaminata*, *Poll. Res.* **7(1–2)**, 23–28.

Cohen, A. C. (1990) Feeding adaptations of some predaceous heteropterans, *Ann. Ent. Soc. Amer.* **83**, 1215–1223.

Delvi, M. R. and Pandian, T. J. (1971) Ecophysiological studies on the utilization of food in paddy field grasshopper *Oxya velox*., *Oecologia* Berlin **8**, 267–275.

George, P. J. E. (1996) Impact of chosen insecticides on three non-target reduviid biocontrol agents (Insecta : Heteroptera : Reduviidae). Ph.D thesis, Manonmaniam Sundaranar University, pp. 117.

James, D. G. (1994) Prey consumption by *Pristhesancus plagipennis* Walker (Hemiptera : Reduviidae) during development, *Australian Ent.* **21**, 43–48.

Jeyaraj, S. (1992) *Integrated Pest Management, pest management and pesticides: Indian scenario*, David,; Namrutha Publications, Madras: Madras, pp. 7–16

Lowry, O. H., Rosebrough, N. J., Farr, A. L. and Randall, R. L. (1951) Protein measurement with the Folin Phenol reagent, *J. Biol. Chem.* **193**, 265–275.

Machale, P. R., Khan, A. K. and Sarojini, R. (1991) Biochemical changes induced by cuprous oxide in the various tissues of the freshwater crab, *Barytelphusa guerinii*, *J. Adv. Zool.* **12(2)**, 115–120.

Maheswari, S. C. and Sehgal, S. S. (1981) Effect of Tepa on nucleic acid and protein contents in the developing red cotton bug *Dysdercus koenigii* Fabr, *Indian J. Ent.* **43(4)**, 341–347.

Mansingh, A. (1972) Effects of farnesyl methyl ether on carbohydrate and lipid metabolism in the tent caterpillar *Malacosoma pluviale*, *J. Insect physiol.* **18**, 2251–2264.

Munson, S. C., Padilla, G. M. and Weissman, M. L. (1954) Insect lipids and insecticidal action, *J. Econ. Ent.* **47(4)**, 578–587.

Nagia, D. K., Kumar, S., Sharma, P. and Saini, M. L. (1990) Relative toxicity of five insecticides to red cotton bug *Dysdercus koenigii* (Fab.), *Uttar Pradesh J. Zool.* **10(1)**, 76–79.

Naik, P. R. and Delvi, M. R. (1984) Effects of insecticide permethrin on dietary water utilization in eri silkworm *Philosamia ricini*, *Proc. Indian Acad. Sci (Anim. Sci.)*, **93(6)**, 497–504.

Neri, I., Ascher, K. R. S. and Mosna, E. (1958) Studies of insecticide resistant anophelines III. A preliminary report on lipid control in some strains of *A. atroparvus*, *Indian J. Malariol.* **12**, 565–570.

Pandian, T. J., Pitchairaj, R., Mathavan, S. and Palanichamy, R. (1978) Effects of temperature and leaf ration on the water budget of the final instar larva of *Danaus chrysippus* L. (Lepidoptera : Danidae), *Monit. Zool. Ital.* **12**, 17–28.

Reddy, G. S. and Rao, A. P. (1982) Biochemical studies on the haemolymph and heart muscle of normal and insecticide treated cockroach *Periplaneta americana*, *Proc. Ind. Nat. Sci. Acad.*, **46(B)**, 164–167.

SAS Institute INC. (1988) *SAS/STAT users guide, Release 6.03 edition*, SAS Institute Inc.: Cary. NC.

Srinivasan, R. (1977) Studies on toxicity of methyl xanthines on chosen organisms. Ph.D thesis, Jawaharlal Nehru University, New Delhi.

Tukey, J. W. (1953) The problem of multiple comparison, Princent University, Princeton, N.J..

Weismann, R. (1955) Neue Erkenutnisse uber das wesen der Insektizidresistenz *Cong. Internatl. Phytopharm. Phytiatr, Journees des Travauz* 69–104.

Weismann, R. and Reiff, M. (1956) Untersuchungen tiber die Bedeutung der Lipoide bei der Insectizidresistenz von *Musca domestica* L., *Varhandl. Naturforsch. Gesell. Basel.* **67**, 311–340.

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Effect of Host on the Consumption Rate, Leaf-Cocoon and Leaf-Egg Ratio of Eri Silkworm, *Samia cynthia ricini* Boisduval

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ABSTRACT: Consumption of food, leaf-cocoon and leaf-egg ratios of Eri silkworm, *Samia cynthia ricini* Boisduval (Saturniidae: Lepidoptera) were studied with local, Aruna and RC-8 varieties of castor (*Ricinus communis* L.) and Tapioca (*Manihot utilissima* Pohl.). The rate of leaf consumption by the larval instar varied with the varieties of the host plant. Leaf-cocoon ratios were higher in Tapioca (19.17 : 1) and lower in Bangalore Local castor (12.17 : 1), but, greater leaf-egg ratios were obtained in local castor (5.08 : 1) and lower in Tapioca (3.40 : 1) leaves.

KEYWORDS: Host plants, consumption, leaf-cocoon ratio, leaf-egg ratio, Eri silkworm, *Samia cynthia ricini*.

INTRODUCTION

Among the non-mulberry-feeding silkworms the Eri silkworm is the only domesticated species. Ericulture is being practiced with unique advantages of easy rearing, resistant to diseases and additional source of income from castor seed. The polyphagous nature of worms advert the estimates of food required during different instars, which is inevitable to be decided the amount of rearing to be taken up and selection of the best host for egg production. Present studies were taken up in order to estimate the amount of food consumed during the larval stages, Leaf-cocoon and Leaf-egg ratios and also to evaluate its dietetics.

MATERIAL AND METHODS

The Eri silkworm, *Samia cynthia ricini* Boisduval (Saturniidae : Lepidoptera) was reared separately on four hosts viz., three varieties of castor, *Ricinus communis* L. (Bangalore Local, Aruna, and RC-8) and Tapioca, *Manihot utilissima* Pohl. (variety: Mangalore Local) till cocoon formation. Each treatment was replicated five times with

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TABLE 1. Instarwise consumption of food (g) by *S. c. ricini*

Host Leaf	Instar I	II	III	IV	V	Total
Castor:Var Bangalore Local	5.258	9.393	50.069	189.311	1257.595	1511.626
Castor:Var Aruna	5.824	8.491	52.280	231.335	1689.189	1987.119
Castor:Var RC-8	5.605	11.594	53.747	236.995	1620.631	1928.572
Tapioca:Var Mangalore Local	4.523	22.469	61.575	213.569	1486.834	1788.970
SEM	0.320	0.739	2.810	5.988	28.710	29.592
C.D ($P = 0.05$)	0.686	1.569	5.964	12.698	60.870	62.736

100 larvae in each replicate. A known quantity of food was offered to the larvae. The standard gravimetric method (Waldbauer, 1968) was followed to measure the food consumption. Once in 24 h, the excreta and uneaten food were carefully separated and weighed.

The grownup worms were picked and left on the mountages for spinning. On the sixth day of spinning, the cocoons were harvested, counted and weighed. The consumption, leaf-cocoon and leaf-egg ratio were calculated adopting the standard formulae.

Weight of food consumed = Weight of food offered − Weight of food remained

Leaf Provided to Cocoon Ratio: It is the ratio of gross quantity of leaves supplied to produce one unit of cocoon.

Leaf Consumed to Cocoon Ratio: It is the ratio of quantity of leaves consumed to produce one unit of cocoon and were calculated adopting the formulae:

$$\text{Leaf cocoon ratio} = \frac{\begin{array}{c}\text{Average weight of food consumed/}\\ \text{Average weight of food offered to a larva}\end{array}}{\text{Average weight of a cocoon}}$$

Leaf-Egg Ratio: It is the ratio of egg produced for the unit of leaves offered/consumed.

$$\text{Leaf egg ratio} = \frac{\text{Average fecundity of a moth}}{\begin{array}{c}\text{Average weight of food consumed/}\\ \text{Average weight of food offered to a larva}\end{array}}$$

The variance between the treatments was calculated adopting completely randomized design (Panse and Sukhatme, 1985).

TABLE 2. Leaf-cocoon ratios of *S. c. ricini* fed on different host leaves

Host	Food offered	Food consumed
Castor		
Bangalore Local	12.17 : 1	8.17 : 1
Aruna	15.02 : 1	9.38 : 1
RC-8	14.12 : 1	8.57 : 1
Tapioca		
Mangalore Local	19.71 : 1	10.15 : 1
SEM	0.36	0.83
C.D ($P = 0.05$)	0.77	0.75

TABLE 3. Leaf-egg ratios of *S. c. ricini* fed on different host leaves

Host	Food offered	Food consumed
Castor		
Bangalore Local	5.08 : 1	3.40 : 1
Aruna	4.37 : 1	2.72 : 1
RC-8	4.46 : 1	2.70 : 1
Tapioca		
Mangalore Local	3.40 : 1	1.80 : 1
SEM	0.23	0.14
C D ($P = 0.05$)	0.48	0.30

RESULTS AND DISCUSSION

Leaf consumption The amount of food consumed by different instars of Eri silkworm is presented in Table 1. The results show that the amount of food consumed on four hosts varied with the stages of instars. But, the food consumption on all the hosts gradually increased till the fourth instar, and a steep and steady phase in the fifth instar (over 83% of the total food consumed). The results are in agreement with those of El Shaarawy *et al.* (1975), Poonia (1978) and Reddy (1983).

The average quantity of food consumed by a larva was 15.11 g, on Bangalore Local, 19.87 g on Aruna, and 19.28 g on RC-8 varieties of castor and 17.88 g on Mangalore local of Tapioca. The observation indicates that the Aruna and RC-8 varieties of castor are preferred. The food preference is mainly governed by its physio-chemical properties (House, 1962) which are responsible for variations in leaf consumption.

Leaf provided to cocoon ratio: The leaf provided to cocoon ratio was significantly low in Bangalore Local of castor (12.17 : 1), but it was high in Mangalore local of

Tapioca (19.17 : 1). The larvae provided with the leaves of Aruna and RC-8 varieties of castor did not differ significantly (Table 2).

Leaf consumed to cocoon ratio: The leaf cocoon ratio of the larvae provided with the leaves of Bangalore Local and RC-8 of castor did not differ significantly. Larvae on Mangalore local of Tapioca had higher Leaf-cocoon ratio (10.15 : 1) followed by Aruna variety of castor (9.38 : 1).

Leaf-egg ratio: The data (Table 3) on leaf-egg ratio indicated that a significant higher number of eggs was yielded a gram of leaf offered and consumed on Bangalore Local variety of castor (5.08 : 1 and 3.40 : 1). The minimum number of eggs was recorded by the consumption of Mangalore local of Tapioca (3.40 : 1 and 1.80 : 1). The egg yielded by the consumption of RC-8 and Aruna varieties of castor did not vary from each other.

It is inferred that the Bangalore local variety of castor is a suitable host for rearing eri silkworm, *Samia cynthia ricini* because of the lowest leaf-cocoon ratio and highest leaf-egg ratio. Aruna and RC-8 varieties of castor and Tapioca stood in serial sequence with regard to their suitability.

REFERENCES

El Shaarawy, M. E., Gomma, A. A. and El Garthy, A. T. (1975) The consumption, digestion and utilization of two castor bean varieties by Eri silkworm, *Attacus ricini* Boisduval, *Z. Angew. Ent.* **70**, 123–128.

House, H. L. (1962) Insect nutrition, *Ann. Rev. Ent.* **31**, 653–672.

Panse, V. G. and Sukhatme, P. V. (1985) *Statistical Methods for Agricultural Workers*, IV Edition. ICAR: New Delhi, p. 359.

Poonia, F. S. (1978) Studies on food utilization and rate of growth during the developmental stages of Eri silkworm *Philosamia ricini* Hutt., *Indian J. Seric.* **17**, 48–60.

Reddy, M. V. (1983) The consumption and utilization of the castor leaves by the larvae of *Philosamia ricini* Hutt. (Lepidoptera:Saturniidae), In *Insect Ecology and Resource Management*, Goel,; pp. 215–217.

Waldbauer, G. P. (1968) Consumption and utilization of food by insects, *Recent Adv. Insect Physiol.* **5**, 229–288.

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Effect of Insect Pathogens on the Larvae of *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae)

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ABSTRACT: A laboratory experiment was conducted to study the efficacy of Nuclear polyhedrosis virus (NPV), *Bacillus thuringiensis* Berliner (*B.t.*) and *Beauveria bassiana* (Balsamo) Vuille. against five instars of *Helicoverpa armigera*. The per cent larval mortalities were higher in all the five instars of *H. armigera* at higher concentrations of NPV., *B.t.* and *B. bassiana*. Higher mortality percentages were observed in the early instars compared to later instars.

KEYWORDS: NPV, B.t., *B. bassiana*, *Helicoverpa armigera*

INTRODUCTION

Gram pod borer *Helicoverpa armigera* has become a very serious threat to crop production in many countries. With more than 181 host plant species in 45 families, it is the limiting factor on crops such as chickpea, pigeonpea, sunflower, cotton, tomato etc. (Manjunath *et al.*, 1985). It is estimated that an average infestation of one larva per plant on pigeonpea can cause yield loss of 1015 kg/ha (Seshu Reddy and Channa Basavanna, 1978). Development of resistance to most of the insecticides led to the utilization of natural pathogens such as Nuclear polyhedrosis virus (NPV), *Bacillus thuringiensis* Berliner (*B.t.*) and *Beauveria bassiana* (Balsamo) vuille. These are highly compatible with other methods of pest control and can fit into the concept of integrated Pest Management. Keeping this in view, the present investigation was undertaken to study the comparative efficacy of these microbial pesticides on gram pod borer and on the effect of larval age and dosage of NPV, *B.t.* and *B. bassiana* on the susceptibility of *H. armigera*.

MATERIALS AND METHODS

The NPV inoculum obtained from the Department of Entomology, S. V. Agricultural College, Tirupati was multiplied by feeding virus contaminated water soaked chickpea seeds to third and fourth instar larvae of *H. armigera*. The purified, concentrated

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suspension of polyhedra isolated from the dead, diseased larvae of *H. armigera* was used as infective material (Padmavathamma, 1988).

'Dipel' a wettable powder formulation of *B.t.* subsp. *kurstaki* obtained from Lupin Laboratories Limited, Bombay was multiplied by feeding bacteria contaminated water soaked chickpea seeds to third and fourth instar larvae of *H. armigera*. The bacteria was isolated from the diseased *H. armigera* larvae and pure culture was prepared from it as described by Kiraly *et al.* (1974). Ten ml of sterile distilled water was added to each agar slant and growth was harvested. The bacterial suspension so obtained was used as stock suspension.

The fungus inoculum obtained from the white muscardine silkworm cadavars from the Department of Sericulture, University of Agricultural Sciences, GKVK, Bangalore, was isolated and multiplied as per Kiraly *et al.* (1974). Then the spores were transferred into a conical flask containing sterile distilled water and were thoroughly shaken for 10 minutes. The suspension was then strained through a double layer sterile cheese cloth and the filtrate used as stock suspension. A standard haemocytometer (Neubaur improved double ruling, Germany) was used for counting the polyhedra and spores of *B.t.* and *B. bassiana* under Meopta phase contrast microscope. Serial dilutions were prepared from the stock suspensions as and when required.

Larvae of uniform age and size from the laboratory culture were used for this study. Five concentrations of NPV (POB/ml), *B.t.* (Spores/ml) and *B. bassiana* (spores/ml) viz., 1×10^9, 1×10^7, 1×10^5, 1×10^3 and 1×10^1 suspensions were used for infecting the larvae. For each concentration, fifty larvae of all instars starved for 6 hours were placed individually in glass vials (7.5 cm × 2.5 cm). Each of the five concentrations of virus, bacterium and fungus were smeared to water soaked bengal gram seeds separately. The suspension had 0.1 per cent teepol which served as wetting agent. The treated seeds were air dried in shade and fed to the larvae for 24 hours. Fresh uncontaminated seeds were supplied daily thereafter. Another set of 50 larvae of each instar were fed with seeds treated with sterile distilled water which served as control. Each treatment was replicated thrice. Observations were made dialy at 24 h interval on larval mortality for each instar and incubation period also recorded. Microscopic examination was conducted in doubtful cases by preparing smears from dead larvae. The percentage larval mortality was analysed after angular transformation.

The experiment was conducted at room temperatures of 27 ± 3°C with a relative humidity of about 70-90%.

RESULTS AND DISCUSSION

Among three pathogens the highest larval mortality (99.78 per cent) was recorded at highest concentration of *B.t.* in the first instar. Similar results were recorded in the case of *Spodoptera litura* (Fab.) by Kamala Jayanthi (1992) who obtained satisfactory control of pest with *B.t.* when compared to NPV and *B. bassiana*.

The susceptibility of larvae was negatively associated with the larval age and positively associated with the microbial concentrations. The highest percentage of larval mortality (76.12) was noticed in first instar compared to the lowest percentage

TABLE 1. Percentage mortality in different larval instars of *H. armigera* fed with different concentrations of NPV, *B.t.*, and *B. bassiana*

Concentration	Instars					
	I	II	III	IV	V	Mean
NPV (POBs ml^{-1})						
1×10^9	95.56	93.78	86.89	76.67	74.67	85.51
1×10^7	89.33	83.65	78.89	72.45	65.55	77.97
1×10^5	80.44	64.89	57.11	49.11	45.11	59.33
1×10^3	74.22	50.22	31.11	25.70	20.00	40.27
1×10^1	63.33	35.56	16.22	10.00	5.77	26.18
Mean	80.57	65.62	54.04	46.80	42.22	
B.t.(spores ml^{-1})						
1×10^9	99.78	94.22	91.33	86.00	80.22	90.31
1×10^7	95.33	87.11	84.00	80.45	70.00	83.38
1×10^5	86.22	81.78	65.78	62.00	60.45	71.25
1×10^3	63.55	56.00	46.00	38.00	30.22	46.75
1×10^1	44.67	37.78	28.45	34.67	18.22	32.76
Mean	77.91	71.38	63.11	60.22	51.82	
B. bassiana (spores ml^{-1})						
1×10^9	90.22	81.56	80.00	72.22	60.22	76.84
1×10^7	78.67	75.33	74.67	58.88	43.11	66.13
1×10^5	63.55	60.22	53.11	44.00	36.00	51.38
1×10^3	58.88	46.89	42.44	38.89	34.00	44.22
1×10^1	58.00	46.67	40.00	36.22	33.78	42.93
Mean	69.86	62.13	57.29	50.04	41.42	
Control	0.00	0.00	0.00	0.00	0.00	0.00
Overall mean	76.12	66.38	58.36	52.36	45.15	

(Significant at 1% and 5% levels) $P = 0.05$ CD Concentrations = 0.193 Instars = 0.386 Concentrations × Instars = 0.862

(45.15) in the fifth instar. *B.t.* proved as most effective agent at highest concentration used (1×10^9 spores ml^{-1}) recording 90.31 per cent larval mortality whereas with NPV lowest larval mortality at lowest concentration (1×10^1 POB ml^{-1}) was obtained. The incubation period recorded for *B.t.*, NPV and *B. bassiana* depending on larval age and concentration of the pathogen are 2-7.5, 3-7.5 and 5-8.5 days respectively. Incubation period increased with larval age and decreased with concentration of pathogens.

Anuradha (1991) and Kamala Jayanthi (1992) reported that larval mortality decreased with decrease in NPV concentration and with the increasing age of the larvae of *S. litura*. Zaz and Kushwaha (1984) recorded similar results with *B.t.* who observed that the mortality of *S. litura* was gradually decreased from first instar to fifth instar and with the decrease in concentration, there was corresponding decrease in mortality. With respect to *B. bassiana* the results are in close agreement with Devaprasad *et al.* (1990) who found a decreased larval mortality of *H. armigera* with increase in larval age or decrease in concentration of the fungus.

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REFERENCES

Anuradha, R. (1991) Studies on control of tobacco caterpillar *Spodoptera litura* with Nuclear polyhedrosis virus on castor *Ricinus communis*. M.Sc. (Ag) Thesis, Andhra Pradesh Agricultural University, Hyderabad.

Devaprasad, V., Jayaraj, S. and Rabindra, R. J. (1990) Susceptibility of gram caterpillar, *Heliothis armigera* to certain entomogenous fungi, *J. Biol. Control* **4**, 44–47.

Kamala, Jayanthi P. D. (1992) Studies on the microbial and Chemical Pesticides in the control of *Spodoptera litura* (Fabricius) (Noctuidae : Lepidoptera). M.Sc (Ag) Thesis, Andhra Pradesh Agricultural University, Hyderabad.

Kiraly, Z. Klement, Z., Solymosy, F., Voros, J., (1974) In *Methods in Plant Pathology*, Kiraly,; 135–272.

Manjunath, T. M., Bhatnagar, V. S., Pacar, C. S. and Sithanatham, S Economic importance of *Heliothis* spp. in India and as assessment of their natural enemies and host plants, In *proceedings of the workshop on biological control of* Heliothis, *increasing the effectiveness of natural enemies*, New Delhi, pp. 197–228.

Padmavathamma, K. (1988) Studies on the nuclear polyhedrosis virus of the Diamond back moth *Plutella xylostella*. Ph. D. Thesis, University of Agricultural Sciences, Bangalore.

Seshu Reddy, K. V. and Channa Basavanna, G. P. (1978) Study on the estimation of loss in redgram due to *Heliothis armigera*, *Science Tech. Ser. 20*, University of Agricultural Sciences: Bangalore.

Zaz, G. M. and Kushwaha, K. S. (1984) Efficacy of *Bacillus cereus* Frankland and Franklan against different instars of *Spodoptera litura* (Fabricius) fed on treated cauliflower leaves, *J. Entomol. Res.* **8**, 216–219.

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Natural Enemies and Host Plants of Spiralling Whitefly *Aleurodicus dispersus* Russel (Homoptera : Aleyrodidae) in Bangalore, Karnataka

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ABSTRACT: The spiralling whitefly *Aleurodicus dispersus* Russel had appeared in very large numbers on several host plants in and around Bangalore. The investigations conducted in 1995–97 had revealed the presence of *A. dispersus* on 45 plant species belonging to 24 families. Of them, 18 species were reported for the first time as host plants for spiralling whitefly. Plants like *Psidium guajava* L., *Michelia champaka* L., *Poinsettia puleherimma* L., *Carica papaya* L., etc., had supported heavy population of *A. dispersus*. Nine species predators were found to attack the spiralling whitefly. Among them, *Cryptolaemus montrouzieri* Muls. and *Mallada astur* Banks were found commonly associated with *A. disperusus*. These local predators did not suppress the outbreak of spiralling whitefly in and around Bangalore. It is suggested to try the exotic aphelinid parasitoid *Encarsia haitiensis* Dozier for the suppression of *A. disperusus* in India.

KEYWORDS: Spiralling whitefly; *Aleurodicus dispersus*; natural enemies; host plants; Karnataka.

INTRODUCTION

The spiralling whitefly, *Aleyrodicus dispersus* Russel is native to Caribbean islands and Central America (Russel, 1965). The problem by *A. dispersus* appears to be new in several African and Asian countries. The incidence of the pest was first noticed on wild tapioca in 1994 at Trivandrum, and later on many plant species in the adjoining areas (David and Regu, 1995). The spiralling whitefly was reported first on guava during 1995 in Bangalore (Mani and Krishnamoorthy, 1996) and later it was found infesting many plants. Since it is a recently introduced pest (Muniappan, 1993; Ranjith *et al.*, 1996), not much information is available on the natural enemies attacking *A. dispersus* in India. The present paper gives a comprehensive list of host plants and the natural enemies of spiralling whitefly that occurred in and around Bangalore.

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MATERIALS AND METHODS

Surveys were carried out from June 1995 to July 1997 at different areas in and around Bangalore. The plant parts infested with *A. dispersus* at road side, parks, kitchen, gardens, several institute and factory premises were collected and preserved. Later the plants were got identified by Dr. S. Joshi, Department of Botany, University of Agricultural Sciences, Bangalore. The shoots of the host plants heavily infested with whitefly were regularly collected and brought to the laboratory. The whitefly infested samples were kept in cloth walled wooden cages (30 × 30 × 30 cm) with glass front. Adults of natural enemies that had emerged were collected and preserved. The identity of the natural enemies was fixed after comparing them with the collections maintained at Project Directorate of Biological Control, Bangalore.

RESULTS AND DISCUSSION

A total of 46 plant species belonging to 24 families were found infested with spiralling whitefly around Bangalore during 1995–97 (Table 1). As many as 44 host plants in Florida, Central and North America (Russel, 1965), 100 in Hawaii (Nakahara, 1978), 60 in Sarawak (Megir-Gumbek, 1987), 27 in Kiribati (Waterhouse and Norris, 1989), 22 in Indonesia (Kajita *et al.*, 1991), 144 in Taiwan (Wen *et al.*, 1994b) and 30 in Sri Lanka (Chandrasekara, 1990), had been reported earlier for *A. dispersus*. Among the plant species, some of them had supported very heavy populations of *A. dispersus*. They included *Psidium guajava* L., *Michelia champaka* L., *Bauhinia purpurea* L., *Cassia fistula* L., *Gossypium hirsutum* L., *Hibiscus* spp., *Pongamia glabra* Vent., *Poinsettia pulcherrima* L., *Carica papaya* L. etc. The leaves of these plant species were completely and thickly covered with whiteflies. In the case of papaya, the fruits were also heavily coated with *A. diserpsus*. All the 46 plant species were reported for the first time as hosts for spiralling whitefly in Karnataka. Plant species like *Butea monosperma* (Lamk.) Taub., *Barleria cristata* L., *Crossandra undulaefolia* Salisb. *Cassia fistula*, *Croton sparsiflorus* Morong, *Gossypium hirsutum* L., *Hisbiscus tilacus* L., *Ipomea palmata*, Forsk, *Grevillea robusta* A. Cunn., *Punica granatum*, *Peltoforum ferrugineum* Benth., *Rhinocanthus* sp. *Syzyum jambos* (L.), Abst. *Tabebubia rossea* Dc. and *Tecoma stans* (L.) H.B. and K. were not reported earlier as host plants for *A. dispersus* in India or elsewhere.

A total of nine species predatory insects belonging to three families under three orders were found to attack *A. dispersus* infesting various plant species around Bangalore in 1995–97 (Table 2). Among them, coccinellids predators were found to be important on the spiralling whitefly in the present study. *A. dispersus* was known to be predated by about 20 species of coccinellids in many areas (Mani and Krishnamoorthy, 1998). *Axinoscymnus puttarudriahi* Kapur was reported for the first time in India on spiralling whitefly. However, the same species had been recorded earlier on *A. disperusus* in Sri Lanka (Wijesekera and Kudagamage, 1990). Kajita *et al.* (1991) had also recorded an undermined species of *Axinoscymnus* in Indonesia on the spiralling whitefly. *A. puttarudriahi* was observed in more numbers in July–August

TABLE 1. Natural enemies of spiralling whitefly

Name	Family and Order
Axinoscymnus puttarudriahi Kapur	Coccinellidae, Coleoptera
Cryptolaemus montrouzieri Muls.	
Cheilomenus sexmaculata (Fab.)	
Chilocorus nigrita (Fab.)	
Acletoxenus indicus Malloch	Drosophillidae, Diptera
Apertochrysa sp.	Chrysopidae, Neuroptera
Mallada astur (Banks)	
Mallada boninesis (Okamoto)	
Chrysoperla carnea (Steph.)	

1996 on guava around Bangalore. According to Wijesekera and Kudagamage (1990), *A. puttarudriahi* appeared to be a potential predator of spiralling whitefly but its impact had not been studied on *A. dispersus* in Sri Lanka. *Cryptolaemus montrouzieri* Muls. was observed feeding on the spiralling whitefly infesting several plant species on many occasions. There was also reduction of whiteflies to some extent when *C. montrouzieri* was observed in large numbers. The same predator was recorded earlier on *A. dispersus* in India (Mani and Krishnamoorthy, 1997) and in Hawaii (Paulson and Kumashiro, 1985). *C. montrouzieri* had been reported as effective predator of mainly mealybugs and some soft scales in India and elsewhere. *Chilocorus nigrita* Fab. was seen on *A. disperusus* infesting guava, *Pongamia glabra, Ficus bengalensis* L. etc. *Chilocorus* spp. were known to prey on the aleyrodids like *Siphoninus phyllireae* Haliday (Pelov and Trenchev, 1973) and *Aleurolobus barodensis* Mask. (Samways, 1984) *C. nigrita* along with *C. montrouzieri* had reduced the incidence of whiteflies in few locations sometimes. All the stages of *Cheilomenus sexmaculata* (Fab.) were observed occasionally on the whitefly infested leaves. The same predator had been recorded earlier on *A. dispersus* in Kerala (Palanisamy *et al.*, 1995) and Indonesia (Kajita *et al.*, 1991). It was also known to feed other whiteflies like *Lipaleyrodes euphoribiae* David and Subramaniam (Mani and Krishnamoorthy, 1995) and *Bemesia tabaci* Gennadius (Venugopala Rao *et al.*, 1989).

Green lacewings were also commonly associated with the spiralling whiteflies. The four species namely; *Apertochrysa* sp., *Mallada boninensis* (Okamoto), *M. astur* (Banks) and *Chrysoperla carnea* (Steph.) were reported for the first time on spiralling whitefly in the present study. Among them, *M. astur* was regularly seen feeding on the spiralling whiteflies. In some instances, there was substantial reduction of whiteflies due to the presence of *M. astur*. Earlier, *C. carnea* was reported feeding on the other whiteflies like *Bemisia tabaci* (Genn.) (Anonymous, 1985) and *S. phyllireae* (Pelov and Trenchev, 1973). Earlier *Chrysopa commonche* (Banks) in Hawaii (Paulson and Kumashiro, 1985) and several other undetermined species of *Chrysopa* in Indonesia (Kajita *et al.*, 1991), Guam (Nechols, 1982). Phonpei (Esguerra, 1987), Fiji (Waterhouse and Norris, 1989) and Sri Lanka (Chandrasekara, 1990) had been recorded on *A. dispersus*, while *C. carnea* was known to feed on the other whiteflies

TABLE 2. Host plants of *Aleurodicus dispersus*

Plant species	Family
Abutilon indicum L.	Malvaceae
Abelmoschus esculentus L.	Malvaceae
Acalypha hispida Burm. F.	Euphorbiceae
Annona squamosa L.	Anonaceae
Barleria cristata L.	Acanthaceae
Bauhinia purpurea L.	Leguminaceae
Butea monosperma (Lemk.) Taub.	Leguminaceae
Calotropis gigantica (L.) R. Br.	Euphorbiaceae
Crossandra undulaefolia Salisb.	Acanthaceae
Carica papaya L.	Caricaceae
Canna indica L.	Cannaceae
Cocos nucifera L.	Palmae
Cassia fistula L.	Leguminaceae
Capsicum annum L.	Solanaceae
Croton sparsiflorus Morong	Euphorbiaceae
Ficus bengalensis L.	Moraceae
Grevillea robusta A. Cunn.	Proteaceae
Gossypium hirsutum L.	Malvaceae
Glyricidia maculata H.B. and K.	Leguminaceae
Hibiscus rosasinensis L.	Malvaceae
H. tiliaceus L.	Malvaceae
Ipomea palmata Forsk.	Convolvulaceae
Jasminum grandiflorum L.	Oleceae
Lycopersicon esculentum Mill.	Solanaceae
Manihot glaziovii Muell. Arg.	Moraceae
Michelia champaka L.	Leguminaceae
Murrya koenigi (L.) Spreng.	Rutaceae
Musa sp.	Musaceae
Peltophorum ferrugineum Benth.	Caesalpiniaceae
Poinsettia pulcherimma L.	Euphorbiaceae
Polyalthia longifolia (Sonnerat) Th.	Anonaceae
Pongamia glabra Vent.	Luguminaceae
Psidium guajava L.	Myrtaceae
Punica granatum L.	Punicaceae
Quisqualis indica L.	Combretaceae
Rhinocanthus sp.	Acanthaceae
Ricinus communis L.	Euphoriaceae
Rosa indica L.	Rosaceae
Syzygium sp.	Myrtaceae
S. jambos (L.) Alst.	Myrtaceae
Santalum album L.	Santelaceae
Terminalia catappa L.	Combretaceae
Tabebuia rosea DC.	Bigononiaceae
Tilicium decipiens L.	Spindaceae
Tecoma stans (L.) H.B. and K.	Bigononiaceae

like *B. tabaci* (Anonymous, 1985) and *S. phyllireae* (Pelov and Trenchev, 1973). The drosophilid *Acletoxenus indicus* Malloch was collected only on two occasions from the whitefly infested plants. It was only of minor importance. The same predator was reported earlier on *L. euphorbiae* (Mani and Krishnamoorthy, 1995).

A total of 5 species of parasitoids were known to attack *A. dispersus* in many countries (Mani and Krishnamoorthy, 1998). Two year collections of spiralling whitefly did not yield any parasitoid in the present study but there was a record of *Encarsia* sp. on the same whitefly in Kerala (PDBC-ICAR, 1998). The local natural enemy complex had failed in suppressing the spiralling whitefly effectively in India and elsewhere, though *C. montrouzieri* and *M. astur* had reduced the populations on some occasions. Since it is an introduced pest in India, it is an excellent target for classical biological control. It would seem to be highly desirable to introduce host specific aphelinid parasitoid *Encarsia haitiensis* Dozier first, followed by *Nephaspis oculatus* (Wingo) and *N. bicolor* (Gordan) if necessary only.

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REFERENCES

Anonymous (1985) Abstracts of papers presented at the 4th meeting on whiteflies in field crops, vegetables and orchards. Feb. 11, 1985, *Phytoparasitica*, **13(1)**, Bet Dagan Israel, 73–79.

Chandrasekara, D. K. (1990) Effect of weather and natural enemies on population variation of the spiralling whitefly (SWF), *Aleurodicus dispersus* Russel (Homoptera, Aleurodidae) Res., Report submitted to the degree of BSC. University of Peradeniya: pp. 26.

David, B. V. and and Regu, K. (1995) *Aleurodicus dispersus* Russel (Aleyrodidae, Homoptera), a whitefly pest new to India, *Pestology* **19(3)**, 5–7.

Esguerra, N. M. (1987) The spiralling whitefly *Aleurodicus dispersus* Russel, *Entomol. Bull.* **No. 1**, pp.

Kajita, H., Samudra, M. and Natto, A. (1991) Discovery of the spiralling whitefly *Aleurodicus dispersus* Russel (Homoptera : Aleurodidae) from Indonesia with notes on its host plants and natural enemies, *Appl. Entomol. Zool.* **26**, 397–400.

Mani, M. and Krishnamoorthy, A. (1995) Natural enemies of the whitefly *Lipaleyrodes euphorbiae* David and Subramanium (Aleyrodidae : Homoptera), *J. Biol. Control* **9**, 102–104.

Mani, M. and Krishnamoorthy, A. (1996) Spiralling whitefly and its natural enemies on guava in Karnataka, *Insect Environment* **2(1)**, 12.

Mani, M. and Krishnamoorthy, A. (1998) Bionomics and biological control of spiralling whitefly, *Aleurodicus dispersus* Russel. (Aleyrodidae, Homoptera), *Madras agric. J.* In Press.

Mani, M. and Krishnamoorthy, A. (1997b) Discovery of Australian ladybird beetle (*Cryptolaemus montrouzieri*) on the spiralling whitefly (*Aleurodicus dispersus*) in India, *Insect Environment* **3(1)**, 5–6.

Megir-Gumbek (1987) Study on control of whitefly, *Annual Report Research Branch Department of Agriculture for the year 1986–87*, p. 83–84.

Muniappan, R. Spiralling whitefly. *The Hindu* dated August 11, p. 28.

Nakahara, L. M. (1978) Hawaii cooperative economic pest report, State of Hawaii, October 20.

Nechols, J. R. (1982) Entomology : biological control. Annual Report, Guam Agricultural Experimental Station: 33–49.

Palanisamy, M. S., Pillai, K. S., Nair, R. R. and Mohandas, C. (1995) A new cassava pest in India, *Cassava News Letter* **19**, 6–7.

Paulson, G. S. and Kumashiro, B. R. (1985) Hawaiian Aleyrodidae), *Proc. Hawaiian. Ent. Soc.* **25**, 103–129.

PDBC-ICAR (1998) Annual Report of Project Directorate of Biological Control for 1997–98, Bangalore, India, pp. 172.

Pelov, V. and Trenchev, G. (1973) The pear whitefly and its natural enemies, *Rast Zash* **21(11)**, 26–27.

Ranjith, A. M., Sitarama Rao, D. and Thomas, J. (1996) New host records of the mealy whitefly *Aleurodicus dispersus* Russel in Kerala, *Insect Environment* **2(2)**, 35.

Russel, L. M. (1965) A new species of *Aleurodicus Douglas* and two close relatives (Homoptera : Aleyrodidae), *Fla. Entomol.* **48(1)**, 47–55.

Samways, M. J. (1984) Biology and economic value of the scale predator *Chilocorus nigrita* (F.) (Coccinellidae), *Biocontrol News and Information* **5**, 91–105.

Venugopala Rao, N., Reddy, A. S. and Tirumala Rao, K. (1989) Natural enemies of cotton whitefly *Bemesia tabaci* in relation to host population and weather factors, *J. Biol. Control* **3**, 10–12.

Waterhouse, D. F. and Norris, K. R. (1989) Biological control. Pacific prospects - supplement 1 ACIAR Monograph, No. 12. pp. 125.

Wen, H. C., Hsu, T. C. and Chen, C. N. (1994b) Supplementary description and host plants of the spiralling whitefly. *Aleurodicus dispersus* Russel, *Chinese J. Entomol.* **14(2)**, 147–161.

Wijesekera, G. A. W. and Kudagamage, C. (1990) Life history and control of spiralling whitefly. *Aleurodicus dispersus* (Homoptera : Aleyrodidae). Fast spreading pest in Sri Lanka 22–25, *Quarterly Newsletter-Asia and Pacific Plant Protection Commission* **33(2)**, 22–24.

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Effect of Weather Parameters on Population Dynamics of Peach Fruit Fly, *Bactrocera zonata* (Saunders)

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ABSTRACT: Studies on population dynamics of peach fruit fly, *Bactrocera zonata* (Saunders) were conducted during April-August, 1997 in north Bihar. Maximum fly population was observed during third week of June (357.0 flies/trap) while minimum during last week of August (14.3 flies/trap). Fly population showed positive correlation with maximum and minimum temperatures, rainfall and negative correlation with relative humidity.

KEYWORDS: *Bactrocera zonata* (Saunders), Population, Weather Parameters.

INTRODUCTION

The peach fruit fly, *Bactrocera zonata* (Saunders) is one of the most dominating fruit infesting fruit flies in India. It was originally described by Saunders in 1841 from Bengal and has been reported from nearly all countries of Oriental region and also from Australian and Palaearctic regions. Fletcher (1917) reported it infesting peaches and mangoes and considered as a minor pest. In recent years, due to enormous increase in its population and host range, it has attained the status of a major pest (Agarwal and Kapoor, 1986). In north Bihar conditions it mainly breeds on mango during summer and rainy seasons. Population studies provide the key to a precise understanding of the natural abundance of the pest and assists to evolve effective and timely control schedules. Both factors, e.g. host availability and weather parameters are major determinants of abundance of dacine fruit flies (Fletcher, 1987). For *Bactrocera zonata* studies related to population have been conducted by using attractants in traps (Batra, 1964; Kapoor *et al.*, 1987). The present paper includes discussion on population fluctuation of *Bactrocera zonata* during its maximum activity period and the factors responsible for the same in north Bihar conditions.

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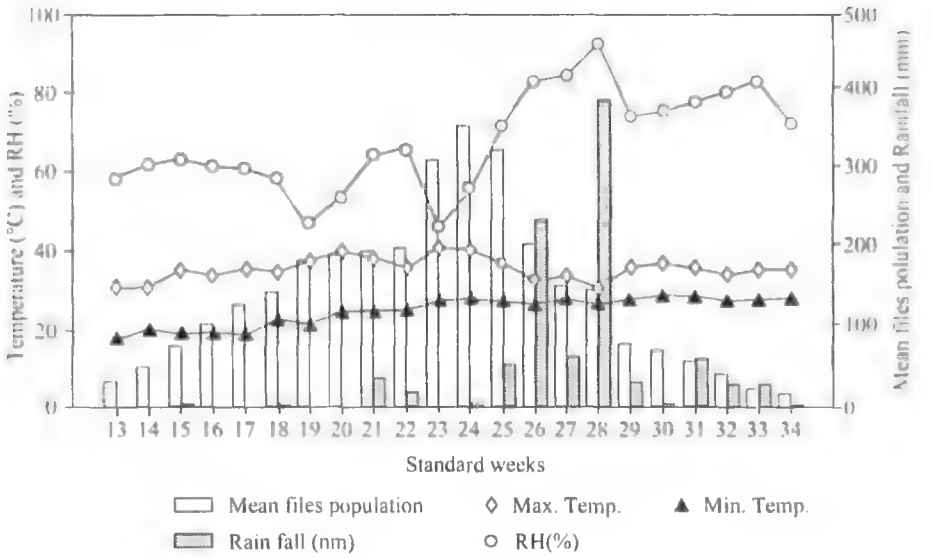

FIGURE 1. Population fluctuation of *Bactrocera zonata* (Saunders) in relation to weather factors.

MATERIALS AND METHODS

In order to study the population build-up of the peach fruit fly, trapping of adult flies was done at Rajendra Agricultural University Campus, Pusa (Samastipur). Three Steiner type traps (each representing a replicate) impregnated with a solution soaked in cotton wicks and consisting of methyl eugenol (2 ml), malathion 50 EC (1 ml) and mango pulp (20 ml) were used for trapping adult males. The traps were replenished at weekly intervals and fly catches were also recorded at weekly intervals. Observations were taken during April-August, 1997 which was the period of availability of its most common host mango. The trapping data were correlated with weather factors to determine their influence on population fluctuations, if any.

RESULTS AND DISCUSSION

Two species of the genus *Bactrocera*, viz. *zonata* and *dorsalis* were trapped. This was because the methyl eugenol had a profound influence on males of many dacine species and a number of closely related species respond to this attractant (Drew, 1974; Kapoor *et al.*, 1987). The results of study pertaining to *Bactrocera zonata* population and its correlation with weather parameters are being discussed.

The adult males were trapped throughout the experimental period. The average number of flies trapped during April-August were 80.7, 180.5, 298.8, 130.5 and 32.8 flies/trap/week. There was a gradual increase in the number of flies trapped from April, reaching at maximum during second to fourth weeks of June. During third week of June highest trap catches were recorded (357.0 flies/trap) (Table 1). A decreasing trend

TABLE 1. Weather parameters and population build up of *Bactrocera zonata* (Saunders)

Month and week 1997		Standard week	Mean male flies population	Temperature (°C)		Mean RH (%)	Rainfall (mm)
				Maximum	Minimum		
April	I	13	34.00	30.5	18.1	58.5	1.5
	II	14	53.00	30.4	20.0	62.0	0.0
	III	15	80.00	34.8	18.8	63.2	2.0
	IV	16	105.00	33.5	19.3	61.5	0.0
	V	17	131.00	35.3	18.6	60.9	0.0
May	I	18	147.00	34.3	22.5	58.0	2.0
	II	19	184.67	36.9	20.9	46.6	0.0
	III	20	193.00	39.5	24.2	53.1	0.0
	IV	21	197.67	37.7	24.2	64.1	36.7
June	I	22	200.00	35.3	24.6	65.3	16.7
	II	23	313.33	40.1	26.5	45.6	0.0
	III	24	357.00	39.6	27.1	55.5	5.4
	IV	25	325.00	36.1	26.4	71.3	52.4
July	I	26	207.00	31.8	25.8	82.4	236.4
	II	27	150.00	32.9	26.9	83.9	61.3
	III	28	145.00	29.7	25.5	91.9	385.5
	IV	29	80.00	35.0	26.9	73.4	29.6
	V	30	70.67	35.8	27.5	74.5	2.0
August	I	31	57.67	34.5	27.5	76.6	60.5
	II	32	40.00	32.9	26.2	79.5	24.0
	III	33	19.33	34.0	26.4	82.2	26.3
	IV	34	14.33	34.0	26.9	71.3	1.2

SEm ± 10.322

was observed in fly population during July and August and from fourth week of July a sharp decline was observed, which reached to lowest level in last week of August (14.3 flies/trap).

To determine the effect of weather factors (Table 1, Fig. 1) fly population (Y) was correlated with the maximum temperature (X_1), minimum temperature (X_2), mean relative humidity (X_3) and rainfall (X_4). Multiple correlation and regressive coefficients were worked out from the data. Both maximum and minimum temperatures exhibited a positive correlation with fly population and the values of 'r' were 0.6195** and 0.2223, respectively. Liu (1983) considered that temperatures below 20°C and above 40°C are primary detrimental for tropical *Bactrocera* spp. and affect mainly development and survival of immature stages and flight activity of adults. In present investigation fly population increased upto the end of June with an increase in temperature and thereafter a decline was observed (Table 1). However, the flies were available throughout the experimental period because of favourable temperature range.

The average relative humidity ranged between 45.6 to 91.9 per cent during the study period and a negative correlation ($r = -0.3709$) between fly population and relative humidity was obtained. Results of earlier studies done on oriental fruit fly,

Bactrocera dorsalis indicated a positive correlation with temperatures and negative with relative humidity (Bagle and Prasad, 1983; Liu, 1983) and similar correlations were also exhibited by *B. zonata* during present investigation.

Rainfall is another limiting factor which had a pronounced influence on the fly population. The rain makes the soil moist and thus provide a favourable condition for eclosion of adults from pupae (Liu, 1983). A positive correlation ($r = 0.0959$) between rainfall and fly population was obtained. However, heavy and successive rains for a longer period are considered to be disadvantageous and after heavy rains (236.4 mm) during first week and (385.5 mm) during third week of July sudden decline in fly population was observed (Table 1). The present findings are in accordance with those of Liu (1983) for *B. dorsalis* population.

The cumulative effect of weather factors on population dynamics of *Bactrocera zonata* was also determined through coefficient of determinant factor R^2 which was 65 per cent ($R^2 = 0.65308$). The regression coefficient for maximum temperature, minimum temperature, relative humidity and rainfall were 19.801, 4.930, −4.280, and 0.722, respectively.

The abundance of larval hosts is another major factor regulating *Bactrocera* populations. Maximum number of flies were trapped during second to fourth weeks of June, which is synchronizing with the peak mango fruiting period. The fly population declined significantly from fourth week of July which may also be due to reduction in availability of mango fruits.

REFERENCES

Agarwal, M. L. Kapoor, V. C., (1986) Indian Dacini (Diptera: Tephritidae) and their host plant relationship, In: *Fruit Flies of Economic Importance*, Cavalloro,: CEC/IOBC adhoc meeting, Hamburg, 1984: Balkema, Rotterdam, pp. 51–56.

Bagle, B. G. and Prasad, V. G. (1983) Effect of weather parameters on population dynamics of oriental fruit fly *Dacus dorsalis* Hendel, *J. Ent. Res.* **7(2)**, 95–98.

Batra, H. N. (1964) Value of clensel as a chemical attractant and preliminary studies on population fluctuations and movement of fruit flies in the orchards, *Indian J. agric. Sci.* **34(1)**, 28–37.

Drew, R. A. I. (1974) The response of fruit fly species (Diptera: Tephritidae) in the South Pacific area to male attractants, *J. Aust. Entomol. Soc.* **13**, 267–270.

Fletcher, B. S. (1987) The biology of dacine fruit flies, *Ann. Rev. Entomol.* **32**, 115–144.

Fletcher, T. B. (1917) Annotated list of Indian crop pests, *Proc. Second ent. Meeting*, Pusa, 241.

Kapoor, V. C., Grewal, J. S. and Beri, A. S. (1987) Fruit fly traps in the population study of fruit flies, *Proc. 2nd Int. Symp. Fruit Flies*, Crete, Greece, 1986, Elsevier Sci. Publ. Co.: USA, p. 461.

Liu, Y. C. (1983) Population studies on the oriental fruit fly, *Dacus dorsalis* Hendel in Central Taiwan, In: *Fruit Flies of Economics Importance*, Cavalloro,: CEC/IOBC Symp., Athens, 1982, Balkema: Rotterdam, pp. 62–67.

Saunders, W. W. (1841) Description of four new dipterous insects from Central and Northern India, *Trans. R. ent. Soc. Lond.* **3**, 60–61.

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Effect of Neem Derivatives on the Safflower Aphid (Dactynotus carthami HRL.)

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ABSTRACT: Intercropping safflower with either wheat or gram did not influence the safflower aphid population. Of the two neem derivatives, neem oil was better than neem kernel extract in significantly reducing the safflower aphid population 1, 3 and 7 days after the first spray (with 74.15, 56.91 and 45.08% pop. reduction, respectively) and second spray (with 49.84, 49.18 and 39.73% pop. reduction, respectively). The neem products were not effective when sprayed a third time. However, treatment with phosphamidon @ 0.03 percent had maximum yield (578.33 g/5 plants), followed by neem oil @ 2 percent (533.33 g/5 plants) and neem kernel extract @ 10 percent (493.33 g/5 plants), which significantly differed among the treatments and the untreated control (461.66 g/5 plants).

KEYWORDS: Neem Derivatives, Safflower aphid population.

Safflower is infested by many insect pests viz., the safflower aphid (*Dactynotus carthami* HRL., *D. jaecae* Linn., *D. compositate* Theobald and *D. sonchi* Linn.), the safflower capsule fly (*Acanthiophilus helianthi* Rossi.), safflower caterpillar (*Perigea capensis* Gue.), the lacewing (*Monanthia globulifera* W.), the lucerne caterpillar [*Spodoptera exigua* (F.)], gram pod borer [*Heliothis armigera* (Hub.)], the stem and flower head borer (*Eublemma rivula* Moore) and the leaf miner [*Phytomyza horticola* (Melgen)]. Of these the safflower aphid, *Dactynotus carthami* HRL., is the major pest and is an important limiting factor in safflower cultivation. Trehan and Halleppanawar (1949) reported 60 to 80 percent infestation by the aphid in Dharwar and Bijapur districts. A yield reduction to the extent of 20 to 25 percent was recorded by Khan and Hussain (1958), more than 35 percent by Bindra and Vaishampayan (1965) and 47 to 74.51 percent by Bharadwaj *et al.* (1990) at Udaipur. The present study was undertaken to evaluate the efficacy of two *neem* derivatives against the aphid of safflower grown as sole crop and under different intercroppings.

The experiment was laid out in a split plot design, comprising three whole units and four sub-units and replicated thrice, during *rabi* 1996–97. The plot size was 5 × 2 m (10 sq.m.). The whole units included: *Safflower sole* - the crop was sown as per recommended agronomic practices maintaining a row to row spacing of 45 cm.

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TABLE 1. Population of aphids on safflower in the untreated plots

Cropping		Average numbers of aphids
Sole safflower		37.85
Safflower + wheat		39.68
Safflower + gram		43.41
	S.Em. ±	4.17
	C. D.	NS

and plant to plant distance of 10 cm.; *safflower + Wheat* (S + W) - the sowing pattern was 4 rows of wheat followed by 2 rows of safflower, rows of safflower were spaced at 45 cm. and those of wheat at 20 cm., and the plants were maintained at 10 cm.; *Safflower + Gram* (S + G) - the pattern of sowing was 3 rows of gram followed by 1 row of safflower, for safflower the rows were spaced 45 cm apart, while that for gram 30 cm. The plant to plant distance for both crops was maintained at 10 cm.

The sub-units consisted of *neem* oil (2%), *neem* kernel extract (10%), phosphamidon (0.03%) as standard check and an untreated control. Three sprayings were made at an interval of 15 days.

Visual population count of aphids from the top 10 cm central shoot of 5 plants, selected at random, was made 24 hours before and 1, 3, and 7 days after the treatments. The observations on population reduction were corrected by applying the correction factor given by Henderson and Tilton (1955). The reduction percentage figures were transformed to arc sine values and subjected to analysis of variance.

Effect of intercropping on the aphid population

Intercropping safflower with either wheat or gram had no significant effect on the population of the safflower aphid. However, in the safflower + gram intercrop the population of aphid on safflower was comparatively more than in the safflower + wheat and sole crop of safflower (Table 1).

Effect of sprayings on the safflower aphid population

The standard check, phosphamidon @ 0.03 percent was most effective in bringing about cent per cent reduction of the aphid population after each spray up to seven days after the treatments. As seen from Table 2, the population of aphids prior to the second spraying was very low (1.0 to 2.67 aphids per 10 cm) in the phosphamidon treated plots, while comparatively more prior to the third spraying (37.33 to 47.0 aphids per 10 cm).

After first spray *Neem* oil (with 74.15% population reduction) gave significantly better control than *neem* kernel extract when observed 24 hours after, but 3 and 7 days after first spray, there was no significant difference between the two *neem* derivatives (Table 3).

TABLE 2. Pre-treatment population of the aphid (*Dactynotus carthami* HRL) on safflower

Cropping pattern	Mean population of aphids (No. per 5 plants)			
	NKE	PO	CONTROL	NO
Before first spray:				
Sole safflower	181.33	81.67	99.33	225.33
Safflower + wheat	218.33	119.67	122.67	188.00
Safflower + gram	156.00	198.67	126.67	197.33
Before second spray:				
Sole safflower	177.66	1.00	265.00	204.33
Safflower + wheat	226.67	2.67	247.00	201.00
Safflower + gram	216.33	1.00	264.00	241.67
Before third spray:				
Sole safflower	504.00	41.67	811.33	405.00
Safflower + wheat	543.00	37.33	763.67	428.00
Safflower + gram	532.00	47.00	740.33	536.00

After second spray *Neem* oil resulted in significantly higher aphid population reduction than *neem* kernel extract 24 hours and 3 days after the treatment, the population reduction percent being 49.84 and 49.18; but after 7 days, the two *neem* products did not show any significant difference. It was also notable that *neem* oil could bring about only up to 50 percent reduction of the aphid population after the first as well as the second sprayings after 3 days, while after seven days lesser (Table 3).

After third spray Both *neem* oil and *neem* kernel extract seemed less effective as they resulted in less than 30, 20 and 15 percent reduction 24 hours, 3 days and 7 days after the spray, respectively (Table 3).

Effect on the yield of safflower

The effect of intercroppings on yield was not significant, however, the yield of safflower in the S + G combination was more than that in S + W or sole crop of safflower. Such a difference in yield could be attributed due to the legume combination in S + G. The chemical treatments registered a significant difference in the mean values for yield. The phosphamidon treatment resulted in maximum yield (578.33 g/5 plants), followed by *neem* oil (533 g/5 plants) and *neem* kernel extract (493 g/5 plants). The two *neem* products significantly differed among themselves and individually with control (461.66 g/5 plants) (Table 4). Bhumannavar and Thontadarya (1979) found phosphamidon @ 0.25 kg a.i. per hectare to give best control of the safflower aphid with maximum increase in the yield. Similarly, Jat and Sharma (1990) also reported that phosphamidon (0.03%) gave maximum yield increase and highest benefit - cost ratio. The interaction effect, though non-significant, indicated that phosphamidon treatments in S + W, S + G and sole safflower resulted in comparatively better yield than the interactions with both the *neem* products.

TABLE 3. Effect of neem on the per cent population reduction of safflower aphid, under different croppings

Treatments	I Spray													
	After 24 hours					After 3 days					After 7 days			
	NKE	PO	NO	Mean		NKE	PO	NO	Mean		NKE	PO	NO	Mean
S Sole	66.03	100	86.82	64.23		70.28	100	56.90	56.93		62.48	99.54	52.89	52.18
	(54.33)	(89.96)	(68.68)	(53.24)^{b}		(56.94)	(89.96)	(48.95)	(48.96)		(52.21)	(86.08)	(46.64)	(46.23)
S + W	53.81	100	78.79	58.58		52.91	100	59.66	53.16		38.56	99.38	98.79	42.34
	(47.17)	(89.96)	(62.55)	(49.92)^{ab}		(46.65)	(89.96)	(50.55)	(46.79)		(38.37)	(85.44)	(98.51)	(40.58)
S + G	54.81	100	53.56	52.09		46.14	100	54.14	50.07		25.95	99.86	43.64	41.23
	(47.74)	(89.96)	(47.02)	(46.18)^{a}		(42.77)	(89.96)	(47.36)	(45.02)		(30.61)	(87.80)	(41.33)	(39.94)
Mean	58.28	100	74.15			56.63	100	56.91			42.09	99.62	45.08	
	(49.74)	(89.96)	(59.42)			(48.79)	(89.96)	(48.95)			(40.40)	(86.44)	(42.16)	
Main treatment (SEm)	(1.737)	C.D. at 5%		(5.096)										
Sub-treatment (SEm)	(2.006)	C.D. at 5%		(5.884)	SEm	(2.034)	C.D. at 5%		(5.966)	SEm	(3.554)	C.D. at 5%		(10.423)
	II Spray													
S Sole	42.50	100	50.10	48.14		41.77	100	51.20	48.23		45.89	100	45.16	47.76
	(40.67)	(89.96)	(45.04)	(43.92)		(40.25)	(89.96)	(45.67)	(43.97)		(42.63)	(89.96)	(42.20)	(43.70)
S + W	42.72	100	49.77	48.12		37.55	100	59.10	49.09		30.00	100	45.58	43.76
	(40.80)	(89.96)	(44.85)	(43.90)		(37.66)	(89.96)	(50.22)	(44.46)		(33.20)	(89.96)	(42.44)	(41.80)
S + G	38.93	100	49.64	47.01		35.13	100	37.32	43.04		21.69	100	28.93	37.18
	(38.33)	(89.96)	(44.78)	(43.27)		(36.33)	(89.96)	(37.64)	(40.98)		(27.74)	(89.96)	(32.53)	(37.96)
Mean	41.23	100	49.84			38.06	100	49.18			32.14	100	39.73	
	(39.93)^{a}	(89.96)^{c}	(44.89)^{b}			(38.08)^{a}	(89.96)^{c}	(44.51)^{b}			(34.52)	(89.96)	(39.06)	
Sub-treatment (SEm)	(0.921)	C.D. at 5%		(2.700)	SEm	(1.287)	C.D. at 5%		(3.776)	SEm	(2.730)	C.D. at 5%		(8.008)
	III Spray													
S Sole	25.27	100	32.31	39.13		16.16	100	13.10	30.83		9.22	100	10.55	27.85
	(30.23)	(89.96)	(34.62)	(38.71)		(23.69)	(89.96)	(21.21)	(33.72)		(17.67)	(89.96)	(18.95)	(31.65)
S + W	25.17	100	29.42	38.31		19.11	100	18.34	33.43		16.57	100	12.04	30.59
	(30.10)	(89.96)	(32.83)	(38.22)		(25.91)	(89.96)	(25.35)	(35.31)		(24.01)	(89.96)	(20.29)	(33.57)
S + G	26.77	100	27.85	38.33		19.49	100	17.96	33.42		14.69	100	13.73	30.56
	(31.15)	(89.96)	(31.84)	(38.24)		(26.19)	(89.96)	(25.07)	(35.30)		(22.53)	(89.96)	(21.74)	(33.56)
Mean	25.77	100	29.84			18.25	100	16.99			13.33	100	12.08	
	(30.49)	(89.96)	(33.10)			(25.26)	(89.96)	(23.88)			(21.40)	(89.96)	(20.33)	
Sub-treatment (SEm)	(0.539)	C.D. at 5%		(1.581)	SEm	(0.522)	C.D. at 5%		(1.531)	SEm	(1.551)	C.D. at 5%		(4.549)

Note: Figures in parentheses are the transformed (Arc sine) values

TABLE 4. Comparative yield (g/5 plants) of safflower under aphid management

	NKE	Po	C	NO	Mean
Safflower sole	490	580	430	510	502.5
S + W	480	580	475	550	521.25
S + G	510	575	480	540	526.25
Mean	493.33^{b}	578.33^{d}	461.66^{a}	533.33^{c}	
Sub-treatment (SEm)	4.317				
Sub-treatment (C.D. at 5%)	12.686				

It was evident that both *neem* products could bring about nearly 50 percent population reduction of the aphids, but with an increase in the aphid population at the time of second spray, and further still, at the third application, these *neem* formulations were less effective. Though *neem* oil was found comparatively more effective than *neem* kernel extract, the kernel extract seemed to have a prolonged residual action. Looking into the exponential growth of the aphid population, especially at the time of third spraying, the use of phosphamidon or any systemic insecticide is suggestive, whereas, the first and second sprayings can be made with the *neem* products, preferably, *neem* oil (2%) at an interval of 7 days rather than 15 days, however, the cost of spraying should also be taken into account.

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REFERENCES

Bharadwaj, S. C., Ashok Kumar,, Bhargava, G. K. and Rana, B. S. (1990) Assessment of losses caused by insect pests in safflower (*Carthamus tinctorius* L.), *Indian J. Appl. Ent.* **4**, 61–70.

Bhumannavar, B. S. and Thontadarya, T. S. (1979) Effectiveness of different insecticides against safflower aphid, *Dactynotus compositae* Theobald on safflower in Karnataka, *Pesticides* **XIII (9)**, 28.

Bindra, O. S. and Vaishampayan, S. M. (1965) Studies on the chemical control of safflower aphid (*Dactynotus compositae* Theobald), *Indian Oilseed J.* **9 (2)**, 113–118.

Henderson, C. F. and Tilton, E. W. (1955) Test with acaricides against the brown wheat mite, *J. econ. Entomol.* **48**, 157–161.

Jat, S. L. and Sharma, J. K. (1990) Relative efficacy and economics of some insecticides against safflower aphid, *Dactynotus carthami* HRL on safflower, *Indian J. Appl. Ent.* **4**, 43–48.

Khan, M. Q. and Hussain, M. (1958) Safflower aphid, *Macrosiphum sonchi* and its control with organophosphorus insecticides, *Proc. 45th Indian Sci. Cong.*, **3**, 463–464.

Trehan, K. N. and Halleppanawar, N. L. (1949) Life history, bionomics and control of safflower aphid (*Macrosiphum jaceae* Linn.), *Current Science* **18 (6)**, 211–212.

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Population Fluctuation of Spiders in the Rice Ecosystem of Tamil Nadu

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ABSTRACT: Spider species distributed in different regions of rice ecosystem of Tamilnadu revealed existence of 21 species belonging to 16 genera in 10 families. Spiders like *Lycosa pseudoannulata*, *Oxyopes javanus*, *Pardosa sumatrana*, *Tetragnatha mandibulata*, *T. maxillosa* and *T. javana* were more populated than other species detected. Population abundance and species diversity of the spiders are found directly related to the growth stages of the rice plant. But there existed a clear cut difference in the occurence of spider species in different regions of rice ecosystem. It was computed that transplanted rice field was found richer in number of spider and their species, species evenness, species diversity and species richness.

KEYWORDS: Spiders, Rice ecosystem, Population fluctuation.

Spiders constitute the major component of the predatory arthropod fauna of rice ecosystem and suppress the populations of the pests like brown planthopper, green leafhopper, white backed planthopper, leaf folder and whorl maggot significantly (Barrion, 1979; IRRI, 1978; Bhathal and Dhaliwal, 1990). It is observed that the spider wealth of the rice ecosystem in Tamil Nadu has not been well documented and hence, the informations pertaining to the spider population is very little and scarce. Thus the present study was carried out to assess distribution and the abundance of spider species in the rice ecosystem during various periods in certain rice tracts of Tamil Nadu.

Population of various spider species computed once in a week in and around Annamalainagar while in distant places namely Ambasamudram, Aduthurai and Tirur assessment was made four times, once in a month during 1993–94. The assessment of the population was done by gathering the spiders from various points in the rice ecosystem such as rice nursery bed, transplanted field, rice field bunds, irrigation channels, and fallow lands adjoining the rice plantation.

(i) Transplanted field

In the transplanted rice, 25 hills were selected randomly at every collection. For population assessment, number of spiders was counted visually and recorded.

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(ii) Rice field bunds and irrigation channels

In the field bunds and the irrigation channels in and around the rice fields, a space of 60 × 30 cm was marked in four sites along the length in each and the spiders were collected and population assessed.

(iii) Rice nursery and fallow land

In rice nursery and fallow lands adjoining the rice fields 1 m^2 area was marked at four places and counts of the spiders were done and specimens gathered.

These specimens were preserved in 70% alcohol and identities made. The assessment of the population was done as below.

Quantitative estimate of abundance

Quantitative estimation of different species and number of individuals in different components of the rice ecosystem was made by subjecting the data derived from the field surveys to the formulae furnished below.

(i) Species diversity (H') was computed based on Shannon - Weiver formula.

$$H' = -p_i / \log_{10} pi$$

where

p_i = Ni/N

Ni = total number of individuals in a species.

N = total number of individuals in all the species encountered.

(ii) Evenness (J') was also calculated to estimate the equitability component of diversity by the formula of Pielou (1975).

$$J' = H' / \log 10^S$$

where S = Species richness

(iii) Richness (ma) was calculated using the formula (Pielou, 1975).

$$ma = \frac{s - 1}{\log 10^N}$$

where s = total number of species collected.

Survey of spiders

The survey of spider species distributed in four rice tracts of Tamil Nadu revealed the presence of 21 species belonging to 16 genera of 10 families (Table 1).

The spiders which were frequented in all the rice tracts included *Clubiona* nr. *drassodes*, *Lycosa pseudoannulata*, *Oxyopes javanus*, *Pardosa sumatrana*, *Runcinia nr. albostriata*, *Tetragnatha javana*, *T. maxillosa* and *T. mandibulata* in the nursery beds. While transplanted rice accommodated all the species of spiders identified except

TABLE 1. Species diversity and distribution of spiders in different situations in the rice ecosystem in Tamil Nadu

Sl. No.	Spider species identified	Family	Situations
1.	*Argiope catunulata* (Doleschall)	Argiopidae	TF
2.	*A. minuta* Karsh	Argiopidae	TF
3.	*Bianor* nr.*angulosus* Karsh	Salticidae	TF, FB, IC FL
4.	*B. hotingcheihi* schenkel	Salticidae	TF, FB, IC FL
5.	*Bianor* sp.	Salticidae	-do-
6.	*Clubiona* nr. *drassodes*	Clubionidae	NY, TF, FB
7.	*Cyrptopthora cicatrosa*	Araneidae	TF
8.	*Dolomedes* sp.	Pisauridae	TF
9.	*Hippasa* sp.	Lycosidae	FB, IC, FL
10.	*Leucauge decorata* (Blackwall)	Tetragnathidae	TF
11.	*Lycosa pseudoannulata* Boes et str.	Lycosidae	NY, TF, FB, IC, FL
12.	*Neoscona theisi* (Walcknear)	Araneidae	NY, TF
13.	*Oxyopes javanus* Thorell	Oxyopidae	NY, TF, FB, IC, FL
14.	*Pardosa sumatrana* Thorell	Lycosidae	NY, TF, FB, IC, FL
15.	*Philodromus* sp.	Philodromidae	TF
16.	*Phlegra* sp.	Thomisidae	TF
17.	*Runcinia* nr *albostriata*	Thomisidae	NY, TF
18.	*Taylorida striata* (Thorell)	Tetragnathidae	TF
19.	*Tetragnatha javana* (Thorell)	Tetragnathidae	NY, TF, FB, IC, FL
20.	*T. mandibulata* Walcknear	Tetragnathidae	NY, TF, FN, IC, FL
21.	*T. maxillosa* (Thorell)	Tetragnathidae	NY, FB, TF, IC, FL

NY - Nursery; TF - Transplanted field; FB - Field bund; IC - Irrigation channel; FL - Fallow land

TABLE 2. Quantitative abundance of spiders of rice ecosystem in Tamil Nadu

Sl. No.	Situations examined	Total no. of individuals in all the species (N)	Number of species detected (S)	Species evenness (J′)	Species diversity (H′)	Species richness (ma)
1.	Nursery	1128	9	1.2717	0.5321	2.6209
2.	Transplanted field	16607	23	1.3612	0.9760	5.2129
3.	Field bunds	5464	14	1.3288	0.7621	3.7458
4.	Irrigation channels	4449	14	1.2723	0.7431	3.8374
5.	Fallow lands	3644	12	1.2930	0.6348	3.0885

Hippasa sp. The field bunds revealed the presence of *Bionar* nr. *angulosus, B. hotingcheihi, Bionar* sp., *C. nr. drassodes, Hippasa* sp. *O. javanus, L. pseudoannulata, P. sumatrana, T. javana, T. mandibulata* and *T. maxillosa*, Likewise irrigation channels harboured species such as B. nr. *angulosus, B. hotingcheihi, Bionar* sp., *Hippasa* sp., *L. pseudoannulata, T. maxillosa, T. mandibulata* and *T. javana*. The adjoining fallow lands had species like *B. nr. angulosus, B. hotingcheihi, Bionar* sp., *Hippasa* sp., *O. javanus, L. pseudoannulata, P. sumatrana, T. javana, T. mandibulata* and *T. maxillosa*.

From the surveys it was observed that spiders like *O. javanus, L. pseudoannulata, P. sumatrana, T. javanus, T. mandibulata* and *T. maxillosa* were more populated than the other species in all the five situations of rice ecosystem.

The population abundance and diversity of the spider species are directly related to the growth stage of the rice plant. During the nursery stage, the wolf spiders, *L. pseudoannulata* and *P. sumatrana* were more prevalent than others. The vegetative stage of the rice crop in the main field harboured jumping and hunting spiders like *B. nr. angulosus, B. hotingcheihi, Bionar* sp and *O. javanus*, while the orb weavers and other sedentary species such as *Argiope catunulata, A. minuta, Neoscona thesi* and *Clubiona* nr. *drassodes* were present at the reproductive stage of the plant. It is significant that *L. pseudoannulata* in particular, was present during all the stages of the rice plant in varying population levels.

These observations are identical with those of Barrion and Litsinger (1984), dela Crux and Litsinger (1986), and Kamal *et al.* (1990). The possible reason for this wide species distribution due to the abundance of lepidopterous pests in all the phases of the rice plant and this feature enables the spiders to subsist on their preys.

Quantitative abundance of spider species

Among the different situations of the rice ecosystem surveyed, transplanted rice field was richer in the number of individuals (16,607), number of species (21), species evenness (1.3612), species diversity (0.9760) and species richness (5.2129) than those of the field bunds, irrigation channels, fallow lands and rice nursery Table 2. This fact is in tune with the observations of Kamal *et al.* (1990). This becomes possible when

varieties of pest population thrive in various regions of the plant canopy and to support the spiders to develop into large numbers in the transplanted rice field.

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REFERENCES

Barrion, A. T. (1979) Arthropod food web of phillippine rice agro-ecosystems. Paper presented at the 10th National Conference of the Pest Control Council of the Phillippines, Manila, Philippines, May 2–5, p. 4.

Barrion, A. T. and Litsinger, J. A. (1984) The spider fauna of Phillipine rice agro-ecosystems. II. Wetland, *Philip. Ent.* **6(1)**, 11–37.

Bhathal, J. S. and Dhaliwal, G. S. (1990) Feeding efficiency of natural enemies of white backed plant hopper. *Sogatella furcifera* (Horvath.), *Indian J. Ent.* **52(2)**, 223–225.

Dela Crux, C. G. and Litsinger, J. A. (1986) Effect of ratoon rice crop on populations of leaf hopper *Nephottetix virescens*, brown plant hopper *Nilaparvata lugens*, white backed plant hopper *Sogatella furcifera* and their predators, *Int. Rice Res. Newsl.* **11(5)**, 25–26.

IRRI (1978) Annual report for 1977, International Rice Research Institute, Los Bonas: Philippines, p. 212.

Pielou, E. C. (1975) *Ecological diversity*, Wiley: New York.

Kamal, N. Q., Odud, A. and Bengum, A. (1990) The spider fauna in and around the Bangladesh Rice Research Institute Farm and their role as predator of rice insect pests, *Philip. Ent.* **8(2)**, 771–777.

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Assessment of Loss Caused by *Polyphagotarsonemus latus* Banks on Chilli

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ABSTRACT: The loss caused by *Polyphagotarsonemus latus* Banks (Acari: Tarsonemidae) on chilli (Capsicum annuum (L.)) was assessed by releasing different populations of the mite on chilli plants, six weeks after transplanting. *P latus* @24, 50 and 100 mites per plant caused significant reduction in yield compared to uninfested plants.

KEYWORDS: Chilli, Pest, *Polyphagotarsonemus latus*

Polyphagotarsonemus latus Banks (Acari: Tarsonemidae) commonly known as the broad mite, yellow tea mite and chilli mite is distributed throughout the tropics (Jeppson *et al.*, 1975). In India, the mite was reported as pest of vegetables and ornamental plants (Awate *et al.*, 1981; Karuppuchamy and Mohanasundaram, 1986; Bose and Yadav, 1989). A survey conducted in 1993 in Kerala revealed the widespread occurrence of the mite on chilli and hence the present study was taken up to assess the loss caused by *P. latus* on chilli.

Crop loss due to *P. latus* was assessed by conducting a pot culture experiment at the College of Agriculture, Vellayani, Thiruvananthapuram. Stock culture of *P. latus* was maintained in potted chilli plants prior to the experiment. Chilli seeds were sown and transplanted in a phased manner three months, prior to the experiment. The variety used was Jwalamukhi. One month old seedlings were transplanted to pots @ one per pot. The treatments for the experiments were *P. latus* released @10, 24, 50 and 100 mites per plant. The mites were released six weeks after transplantation. Chilli plants sprayed with monocrotophos 0.05 per cent at fortnightly intervals served as control. The experiment was laid out in CRD with four replications.

The weight of fruits per plant in each treatment was recorded at the time of harvest. Development of damage symptoms on chilli due to invasion of *P. latus* was observed and recorded at weekly intervals after the release of the mite. The damage symptom assessed on a 0–6 point scale newly evolved for the present study is detailed as follows.

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TABLE 1. Damage grade indices in leaves and mean weight of fruits per chilli plant at different population levels of *Polyphagotarsonemus latus*, released six weeks after planting

Treatments	Weeks after release				Mean (Treatments)	Mean weight of fruits/plant(g)
	1	2	3	4		
10 mites/plant	1.00 (1.41)	1.00 (1.41)	3.00 (2.00)	5.00 (2.45)	2.31 (1.82)	121.25
24 mites/plant	1.23 (1.49)	1.73 (1.65)	4.00 (2.24)	5.24 (2.50)	2.88 (1.97)	112.50
50 mites/plant	2.24 (1.80)	2.74 (1.93)	4.74 (2.40)	6.00 (2.65)	3.79 (2.19)	61.50
100 mites/plant	2.00 (1.73)	3.00 (2.00)	5.00 (2.45)	6.00 (2.65)	3.88 (2.21)	60.50
Control (Monocrotophos sprayed at 0.05%)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0 (1.00)	152.50
Mean (Weeks)	1.22 (1.49)	1.56 (1.60)	3.08 (2.02)	5.00 (2.45)	CD for treatments	0.070
					CD for weeks	0.041
					CD for treatments Vs Weeks	0.090
					CD for yield	35.77

Figures within parentheses are $\sqrt{x+1}$ values

	Damage grade index (DGI)
No crinkling	0
Initiation of crinkling	1
Presence of slight crinkling on leaf	2
Crinkling of leaves + tendency of leaves for downward curling	3
Downward curling of leaves	4
Downward curling of leaves + slightly tubular leaves	5
Downward curling of leaves + narrow tubular leaves	6

Data on damage grade index (DGI) determined for different population levels of *P. latus* are presented in Table 1. There were significant differences in damage grade indices with respect to the various treatments. Maximum damage occurred to plants infested with 100 mites per plant as indicated by the damage grade index (3.88) followed by plants released with 50 mites (3.79), 24 mites (2.88) and 10 mites (2.31). All the treatments were significantly different. Earlier Karuppuchamy *et al.* (1994) reported that feeding of *P. latus* caused severe damage to chilli crops at flowering and fruiting stages and the feeding resulted in sudden crinkling and curling of leaves. In

the present study the sequence of development of symptoms at different population levels of the pest has been elucidated.

The data on fruit yield, (weight of fruits) is presented in Table 1. In control, where chilli plants were protected by spraying monocrotophos 0.05 per cent no damage symptom was observed and the fruit yield was the highest (152.50 g/plant). The mean weight of fruits (121.25 g/plant) in plants released with initial loads of 10 mites per plant was on par with control indicating that chilli plants could tolerate low levels of mite population without adversely affecting the yield. The weight of fruits recorded from plants released with 24 mites per plant was significantly higher (112.50 g/plant) than that from plants released with 50 and 100 mites per plant. The damage grade indices recorded in these plants also indicated a similar trend. The results of the present study indicate that *P. latus* is an important pest of chilli which cause significant yield loss even at populations of 24 mites per plant six weeks after transplantation. At higher population of fifty or more mites per plant the loss caused will be substantial. The study conducted by Kareem *et al.* (1977) also indicated that chilli crop failed to yield if *P. latus* infested at flowering and fruiting stage of the crop.

REFERENCES

Awate, B. G., Gandhale, D. N., Naik, L. M. and Patil, A. Q. (1981) Chemical control of mite *Polyphagotarsonemus latus* on chilli *Capsicum annum* L., *Indian J. Plant Prot.* **9**, 193.

Bose, T. K. and Yadav, L. P. (1989) *Commercial flowers*, Naya Prakash Bidhan Sarani: Calcutta, p. 875.

Jeppson, L. R., Keifer, H. H. and Baker, W. W. (1975) *Mites injurious to economic plants*, University of California press: California, p. 614

Kareem, A., Thangavel, P. and Balasubramanian, M. (1977) A new mite *Hemitarsonemus latus* Banks (Tarsonemidae Acarina) as a serious pest of chilli *Capsicum annum* L., *pesticides* **11(6)**, 42–43.

Karuppuchamy, P. and Mohanasundaram, M. (1986) Control of chilli 'Murnai mite', *TNAU Newsletter* **15(10)**, 2.

Karuppuchamy, P., Balasubramanian, G., Sundarababu, P. C. and Gopalan, M. (1994) A potential predator of chilli mite, *Polyphagotarsonemus latus* (Banks) Tarsonemidae : Acari), *Madras Agric. J.* **81(10)**, 552–553.

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Spiders Associated with *Proutista moesta* (Westwood) (Homoptera : Derbidae), A Vector of Phytoplasma Diseases of Palms

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ABSTRACT: Fiftysix species of spiders associated with *Proutista moesta* were recorded. The hunting spider, *Marpissa tigrina* was the most abundant species observed throughout the period. The predatory potential of *M. tigrina*, under laboratory conditions, was 3.3 *P. moesta*/day.

KEYWORDS: *Proutista moesta*, Vector, *Marpissa tigrina*, Predatory potential.

The planthopper, *Proutista moesta* (Westwood) is associated with areca palm, coconut palm and oil palm (Nair and Menon, 1963; Rajan and Mathen, 1985; Wood, 1968). This planthopper is the vector of root (wilt) disease of coconut palm (Anonymous, 1996), yellow leaf disease of areca palm (Ponnamma, 1994) and a putative vector of spear rot disease of oil palm (Kochu Babu, 1995). Ponnamma and Karanavar (1996) reported that the natural enemy complex- a strepsipteran parasitoid and predators, such as, spiders and earwigs play an important role in the biological suppression of this vector. Spiders play a vital role in the natural suppression of several pests of crops. According to Kiritani *et al.* (1972) spiders are the most important factors responsible for nymphal mortality. Riechert and Lockey (1984) emphasized the importance of spiders in the biocontrol of various pests. Sathiamma *et al.* (1987) reported 26 species of spiders belonging to twelve genera and six families from coconut gardens infested with *Opisina arenosella*. On the basis of the above reports, a systematic attempt was made to study the role of these predators on the natural suppression of *P. moesta*. Survey conducted during 1994–1995 in oil palm and areca plantations, Kerala revealed the presence of a rich fauna of spiders in association with *P. moesta* on palms and in breeding sites (decaying materials). The main objective of this study was to identify the spider fauna associated with *P. moesta*, the seasonal abundance of the prominent species, its predatory behaviour and feeding potential.

Different species of spiders were collected at frequent intervals from oil palm plantations of CPCRI, Research Centre, Palode (40 ha.), OPIL, Chithara (3 ha.), PCKL, Chalakkudy (5 ha.) as well as from private plantations in Kuravilangad (2 ha.)

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and Kuttanad (1 ha.) during the period of survey. From the breeding sites, spiders were collected using pitfall traps provided with ethylene glycol as preservative. The seasonal abundance of predominant species was studied at CPCRI, Research Centre, Palode, Kerala. Observations were made on 40 palms from October, 1994 to September, 1996 at weekly intervals. The spiders got identified by Zoological Survey of India, Calcutta. Fiftysix species of spiders were found associated with *P. moesta*. Since *Marpissa tigrina* was found more abundant on palms compared to other species detailed studies were carried out using *M. tigrina*. Field collected female spiders were used to study the predatory behaviour and feeding potential. Spiders were reared in conical flasks (250 ml). *M. tigrina* starved for 24 hours were released in conical flasks containing *P. moesta* (ten each) provided with oil palm leaflets. After 24 hours, the number of *P. moesta* consumed was assessed. Prey density was made constant by the addition of planthoppers. The leaflets were changed on alternate days. Feeding potential was assessed for a period of ten days.

The spider fauna collected from breeding sites of *P. moesta* include 56 species belonging to 26 genera and 15 families (Table 1). Studies on the seasonal abundance of the predominant species of spiders revealed that the hunting spiders (salticidae) form the major group. Among the hunting spiders, *M. tigrina* was the most abundant species observed throughout the period under observation. Sathiamma *et al.* recorded *M. tigrina* as a predator of *O. arenosella* in coconut plantations and reported that the consumption rate of females were more. The maximum population was observed during July–August in the coconut plantation. In the present studies, maximum population was observed during October–December and minimum during February–May (Fig. 1). From May onwards there was a gradual increase in the population. When the population of *M. tigrina* was high, the *P. moesta* population was at a low level during October–December period. It was also observed that population of *P. moesta* during January to April was at a low ebb. When the spider fauna was less abundant during April–September, build-up in the population of *P. moesta* was observed.

TABLE 1: Spider fauna associated with *P. moesta* infested gardens (Oil Palm & Arecanut)

Family	Name of spider	
Araneidae	*Argiope pulchella* Thorell	
	Argiope aemula (Walek)	
	Argiope sp.	(Collection 20)
	Argiope sp.	(Collection 55)
	Argiope sp.	(Collection 1)
	Argiope sp.	(Collection 51)
	Argiope sp.	(Collection 21)
	Argiope sp.	(Collection 8)
	Argiope sp.	(Collection 27)
	Argiope sp.	(Collection 5)
	Argiope sp.	(Collection 18)
	Araneus sp.	(Collection 6)
	Araneus sp.	(Collection 7)
	Neoscona mukerjei Tikader	(S-25)
	Neoscona sp.	

Table 1 Continued...

Family	Name of spider	
	Cyrtophora sp.	
	Leucauge sp.	
Clubionidae	*Cheiracanthium* sp.	
Salticidae	*Marpissa tigrina* Tikader	
	Marpissa sp.	(Collection 36)
	Marpissa sp.	(Collection 40)
	Marpissa sp.	(Collection 41)
	Marpissa sp.	(Collection 43)
	Marpissa sp.	(Collection 52)
	Marpissa sp.	(Collection 53)
	Phidippus bengalensis Tikader	
	P. indicus	
	Salticus ranjitus Tikader	
	Salticus sp.	
	Euophrys sp.	
	Plexippus paykullii (Aud.)	
	Myrmarachne sp.	
	Eris sp.	
Oxyopidae	*Oxyopes* sp.	
Heteropodidae	*Heteropoda* sp.	
	Olios sp.	
Scytodidae	*Scytodes* sp.	(Collection 57)
	Scytodes sp.	(Collection 68)
Lycosidae	*Paradosa heterophthalmus* (Simon)	
	Paradosa sumatrana (Thorell)	
	Paradosa sp.	(Collection 2)
	Paradosa sp.	(Collection 15)
Theridiidae	*Theridion* sp.	(Collection 58)
	Theridion sp.	(Collection 60)
	Theridion sp.	(Collection 61)
	Theridion sp.	(Collection 67)
	Theridion sp.	(Collection 71)
Oonopidae	*Triaeris* sp.	(Collection 63)
	Triaeris sp.	(Collection 65)
Lyssomanidae	*Lyssomanes* sp.	(Collection 53)
	Lyssomanes sp.	(Collection 74)
Tetragnathidae	*Tetragnatha andamanesis* Tikader.	
Uloboridae	*Uloborus* sp.	
Sparassidae	*Sparassus* sp.	
Pholcidae	*Crossopriza* sp.	
Thomisidae	*Thomisus* sp.	

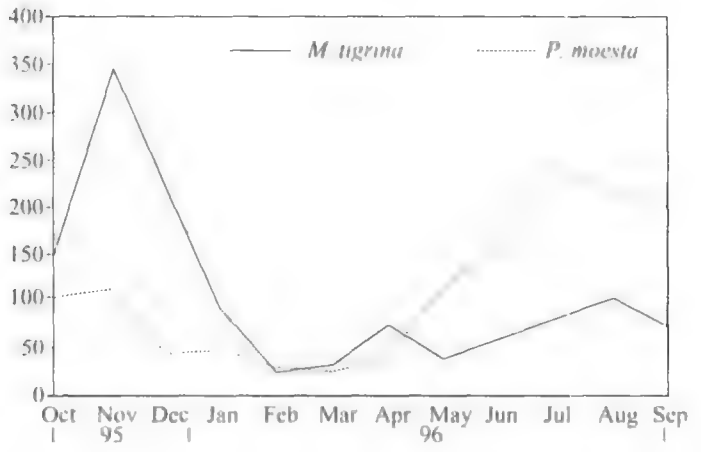

FIGURE 1. Seasonal abundance of *Marpissa tigrina* in Oil palm plantations.

The predatory potential of the predominent species, *M. tigrina* was 3.3 *P. moesta*/day (Table 2).

Similar to other hunting spiders, *M. tigrina*, when locates the planthopper, slowly moves towards the prey and jumps over it. Then holds it with the stout and toothed chelicera and make it inactive. When the prey is paralysed, it feeds on the planthopper leaving behind the wings.

The rate of predation of *M. tigrina* may vary under field conditions compared to controlled conditions in the laboratory. Sathiamma *et al.* (1987) recorded the feeding rate of female *M. tigrina*, *M. dhakuriensis* and *Marpissa* sp. The rate of consumption was 0.30, 0.62 and 0.30 caterpillars of *O. arenosella* respectively. But the male *M. dhakuriensis* consumed only 0.16 caterpillars per day. Sadana (1991) reported that *M. tigrina* was an efficient predator for the control of *Diaphorina citri* and that *Marpissa* spp. found feeding on the nymphs of *Pyrilla perpusilla* on sugarcane in Punjab.

The present study clearly indicated that spiders form an important group of biocontrol agents effecting natural suppression of the field population of the planthopper, *P. moesta*, the vector of three major diseases of palms in Kerala.

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TABLE 2. Feeding potential of *Marpissa tigrina*

Days	R	E	P	L	I	C	A	T	I	O	N	S	Average
	1	2	3	4	5	6	7	8	9	10			
1	5	4	4	5	5	5	5	5	6	6			5.0
2	2	3	5	4	2	3	6	6	5	5			4.1
3	5	5	3	4	4	4	3	3	5	2			3.8
4	5	4	3	5	4	5	3	5	2	3			3.9
5	4	4	3	3	2	3	2	3	2	4			3.0
6	4	4	3	3	2	3	2	3	2	4			3.0
7	6	4	3	5	2	1	4	5	4	3			3.7
8	3	4	2	2	2	3	1	1	2	2			2.2
9	3	3	2	2	2	2	1	1	2	2			2.0
10	2	3	4	1	2	1	2	1	2	5			2.3
Total	39	38	32	34	27	30	28	33	32	36			3.3

REFERENCES

Anonymous, (1996) *Research highlights for 1995–96*, Central Plantation Crops Research Institute: Kasaragod, Kerala, pp. 13.

Baily, C. L. and Chada, H. L. (1968) Spider populations in grain Sorghum, *Ann. Ent. Soc. Amer.* **61**, 567–571.

Kiritani, K., Kawahara, S., Sasaba, T. and Nakasuji, T. (1972) Quantitative evaluation of predation by spiders on the green rice leafhopper, *Nephotettix cincticeps* Uhler, by a sight-count method, *Res. Popl. Ecol.* **13**, 187–200.

Kochu Babu, M. (1995) Investigations on spear rot complex of Oil Palm (*Elaeis auineensis* Jacq.). Ph.D. Thesis, Mangalore University, 178.

Nair, R. B. and Menon, R. (1963) Major and minor pests of arecanut crop *Areca catechu* Linn, *Arecanut J.* **14**, 139–147.

Ponnamma, K. N. (1994) Studies on *Proutista moesta* (Westwood) population dynamics, control and Role as a vector of yellow leaf disease of arecanut. Ph.D. Thesis, University of Kerala, 153.

Ponnamma, K. N. and Karanavar, G. K. (1996) Biology, bionomics and control of *Proutista moesta* Westwood (Hemiptera: Derbidae), a vector of yellow leaf disease of areca palms, Abstract, PLACROSYM XII. 27th to 29th November 1996, 74.

Rajan, P. and Mathen, K. (1985) *Proutista moesta* (Westwood) and other additions to insect fauna on coconut palm, *J. Plant. Crops.* **13(2)**, 132–135.

Riechert, S. A. and Lockey, T. (1984) Spiders as biological control agents, *Ann. Rev. Entomol.* **29**, 299–320.

Sadana, G. L. (1991) Mode of hunting and functional response of the spider, *Marpissa tigrina* Tikader (Salticidae: Arachinidae) to the density of its prey *Diaphornia citri.*, *Entomon* **16(4)**, 301–303.

Sathiamma, B., Jayapal, S. P. and Pillai, G. B. (1987) Observations on spiders (Order: Araneae) Predacious on the coconut leaf-eating caterpillar *Opisina arenosella* Walk. (*Nephantis serinopa* Meyrick) in Kerala: Feeding potential, *Entomon* **12(1)**, 45–47.

Wood, B. J. (1968) *Pests of Oil Palm in Malaysia and their control*, Wood,: The Incorporated Society of Planters: Kuala Lumpur, Malaysia, 75.

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BOOK REVIEW

Insect Pests of Cereals and Their Management

Applied Entomology Volume–I

Editors: **Anand Prakash and Jagadiswari Rao**
Publishers: Applied Zoologists Research Association (AZRA), Central Rice Research Institute, Cuttack, India
Price: Rs. 200, Page V+168

'Insect Pests of Cereals and Their Management' is a multiauthored book. It is a compilation of 12 contributory chapters. The contents of the book is divided into two sections. Section A deals with insect pests of rice, the major crop of India and Section B contains details of insect pests of sorghum, maize, pearl millet, other minor millet, wheat, barley, oat and rye. Section A comprises 8 chapters covering pests like rice stem borers, gallmidge, planthoppers, green leaf hoppers, rice hispa, mealy bugs, cutworms, grasshoppers, termites and other minor pests. Section B includes 4 chapters describing insect pests of sorghum and other cereals. Each chapter of this book contains an introduction, taxonomic status, biology, distribution, host range, economic loss, control measures and management procedures and recent references. It is noteworthy that the contributors of the volume are researchers who are working/worked in the respective field of Applied Entomology. Moreover, the colour photographs provided in many cases are adding the quality of the book. The book avoids unnecessary explanation and directs the reader right to the topic. This book is of great use to the students and researchers of Applied Entomology/Zoology and is good handbook to farmers. The editors are appreciated for compiling such a contribution.

Mariamma Jacob

ELECTRONIC VERSION OF ENTOMON

INTRODUCTION

In 1665, *Journal de Sçavants*, the first scholarly journal was launched, followed a few months later by the *Philosophical Transactions of the Royal Society of London* which is still in existence. Since then, very little has changed in the scholarly publishing industry. However, in the last few years, changes abound, fuelled by the advent of World Wide Web. Publishers realize that on the one hand the market is demanding electronic publishing, and that on the other hand they can do a better job with more efficient production and distribution. What is the long-term outlook?

WHAT ARE PUBLISHERS DOING NOW?

Often headed by the large learned societies, publishers have instigated many initiatives on the Web. These include

1. Altering services on the Web: these are mostly free of charge, and include lists of contents and often abstracts. Surrounding infrastructures such as search engines are also provided. Good examples can be found on the AGU web pages (`http://www.agu.org/pubs/inpress.html`). The National Center for Petroleum Geology and Geophysics offers an excellent overview of the web-presence of earth science journals (`http://www.ncpgg.adelaide.edu.au/journals.htm`). Publishers hope that giving this service to the potential readers will lead to an increased readership and exposure of their journals.
2. Publish "unprintable" items on the web, such movies, sound, or computer programmes which are connected to conventionally published articles. Elsevier publishes sound files with journals for instance, *Speech Communication*.
3. Making existing journals electronic: Springer (`http://link.springer.de/ol/gol`) has most of its journals in pdf format which basically offers readers the possibility of reading (or printing) the articles in exactly the same form as they are printed in their respective journals.
4. Real electronic journals in HTML format: One early example would be *Earth and Planetary Science Letters* (`http://accept.elsevier.nl/journals/epsl/Menu.html`), which features electronic datasets, and also provides the abstracts of the literature references.

IS ALL THIS REALLY ANY BETTER?

The above services do have their nice aspects, but on the whole we do not necessarily believe that they will undermine the popularity of the printed journal issue. Yes, it is convenient not to have to go to the library any more to read a journal, but the

amount of full-text journals available from the desktop is still very low. And, as most WWW publications imitate the printed product, how can one improve on the magnificent interface offered by the print medium? This has developed from the ancient times of clay tablets and book scrolls and now the interface of a paper issue has not only page numbers, a list of contents and keyword indexes but also ease of reading, convenience of flicking through pages, and portability. There is simply no comparison with a computer screen, which is not portable, awkwardly hard to read, even harder to browse, may have inexorably slow connection times, and from time to time a breakdown. Uncertainties also exist concerning the future: for example, will a pdf file still be eligible with the equipment that will be used in 2098?

OUTLOOK

One could anticipate that for a successful electronic product there should be emphasis on completeness, and on the additional values of the features offered by web-technology, I believe that the following points are essential ingredients for this:

1. **Complete offering and easy usage**: Scientists are more likely to go to electronic literature, once this offers a fairly complete overview. Thus, publishers should link their services using the same standards for representation and interface.
2. **To achieve eternal preservation, articles should be stored in a generic format**. Many publishers (including the IEEE, ACM and Elsevier) adhere to SGML (Standard General Mark-up Language), which allows them to generate articles in a *contemporary* format (at this time is conventional print, pdf and HTML3.2; five years ago it was postscript and HTML1.0. With SGML the text is exhaustively coded (tagged). For instance, literature references are tagged, detailing author name, journal, publication date and so on. This allows a publisher to link references to abstracts automatically, and even to link to the referenced article.
3. **Good searching methods** — not a search engine based on inanimate-like boolean logic, but a "fuzzy logic" search mechanism, using natural language as well as good thesaurus. Who knows, may be finding the information will become more important than the information itself.
4. **Link the primary literature with secondary literature**. Wouldn't it be great to do searches on information servers, and be hyperlinked immediately with the full-text of articles resulting from your search? And conversely, while reading an article, being able to click on the literature references and go to the abstract (or better still, to the article in full text — if within the database).
5. **Use the medium to the fullest**.
   * Multimedia files, such as animations, movies and sound; Java code
   * "Living" articles; articles that can be continuously revised and updated after publication
   * Computer programme code, plus test runs.

A journal publication featuring a number of the above points is *Earth & Planetary Science Online*, or *Bulletin of Mathematical Biology* which boasts a link with a secondary database and has HTML and pdf articles generated SGML code, as well as multimedia files (called datasets).

In order to put our journal on the web we have to devise a system that needs to be agreed upon and production of impeccable SGML code needs to be arranged with the typesetter. Our model is that of Elsevier Science, which now has 100 life sciences journals available in HTML/pdf in the project "science direct", which has a direct link with EMBASE, Elsevier's abstracting/indexing system in the life sciences. We hope to extend this in a limited way to our journal, and I hope Entomon (with links to the abstracting/indexing services will soon be included.

The traditional added values of the publishing industry, such as composing, printing and distributing of articles are vanishing. And, although the paper publication medium is hard to beat, I am sure that the publishing industry is developing electronic publication systems which really will make an impact on how scientists will consume the life science literature in the future, improving the efficiency considerably.

ENTOMON is going electronic from the first issue of 1999. Enquiries concerning subscription may kindly be directed to the Managing Editor by email at `dmur@vsnl.com`. A demo version of all the articles of current issue is available on the web at `http://www.river-valley.com/entomon` for your perusal, downloading and comments. The print version of the articles in `pdf` format which looks exactly like the printed journal with same page numbers, etc. are also available for download.

Any reactions to the above will be highly welcome.

Dr. D. Muraleedharan
Managing Editor, ENTOMON
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